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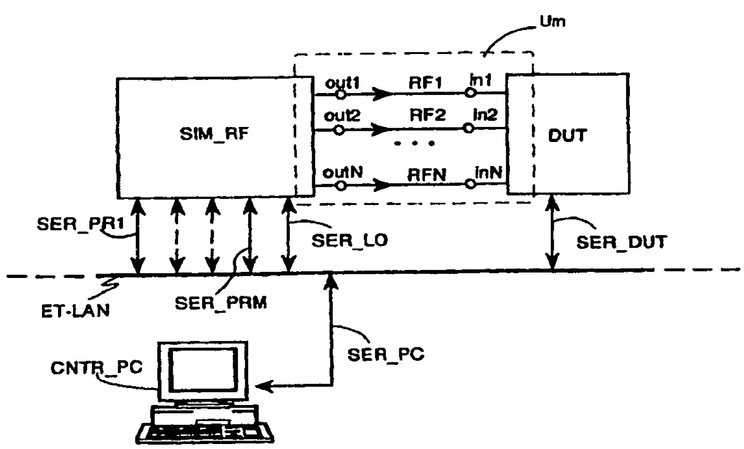

(57) Abstract

It is described a testing system of the receivers of a base transceiver station for cellular telephone systems, for instance GSM 900 MHz, or DCS 1800 MHz, or TACS, etc., equipped with intelligent array antenna having N sensors. The system consists of a radiofrequency scenario simulation equipment (SIM_RF), governed by a control processor (CONTR_PC), both connected to the bus of an Ethernet network, to which the device under testing (DUT) is also connected. The simulation equipment generates on N outputs (out1, out2..., outN) a complex signal consisting of N identical radiofrequency signals (RF1, RF2,.., RFN) differing among them for a phase progessive value. These signals are withdrawn by a same number of coaxial cables and conveyed towards the N antenna input connectors (in1, in2,..., inN) of the radiofrequency signals of the receiver to be tested. The N test signals are obtained through local generation of as many groups of N digital isofrequential carriers as are required to simulate the directions of a useful signal with an arbitrary number of echoes of the same, and the directions of an arbitary number of isofrequential interferent carriers, and not, with their relevant echoes. The N carriers of each group are then modulated with appropriate modulation and digitally multiplied by a same number of relevant beamforming coefficients producing, within each group, an ordering according to gradually increasing phase values.

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"SIMULATION PROCESS OF RADIOFREQUENCY SCENARIO IN RADIO MOBILE ENVIRONMENT AND TESTING SYSTEM EMPLOYING SAID PROCESS"

Field of the Invention

The present invention relates to the field of test systems for telecommunication equipment and more in particular to a radiofrequency scenario simulation process in mobile radio environment for the testing of receivers of base transceiver stations with intelligent antennas, and testing system employing said process.

Before introducing the art known in the field of the invention, it is necessary to briefly describe the operation and problems related to the use of the so-called "intelligent" antennas; to justify, in the applicant's opinion, the lack of testing systems oriented to such a kind of antennas.

As it is already known, the use of intelligent antennas commences in the mobile radio environment to render the reutilization of the same carrier frequencies in cells of adjacent clusters less critical. This critical character is particularly evident in high traffic urban environment, where reutilization distances can suffer a considerable reduction due to the reduced dimensions of the cells, often of some hundreds of metres only. The use of traditional omnidirectional antennas, or of trisectorial ones, involves high interference problems in these particular environments by isofrequential signals coming from adjacent clusters. This is due to the scarce directivity of the antennas, which consequently involves the transmission of comparatively high power signals by the base transceiver stations (BTS). On the contrary, the intelligent array antenna, is a directive radiant system, able to concentrate the electromagnetic field in the original estimated direction of the signal transmitted by a generic mobile MS (in all the directions of the azimuth plane), separately for all the mobiles of a cell where the antenna is allocated. The antenna is therefore characterized by dynamic radiation diagrams (as many as are the time division carriers assigned to the BTS multiplied by the number of time slots) fit with main lobes of reduced angular opening that follow up the directions of the relevant mobiles, thus avoiding to vainly leak power out of these directions. Reciprocally in reception, this involves a reduction of the total level of isofrequential interferents and, consequently, of the reutilization distance of the same carriers, and therefore of the dimensions of clusters.

It is also known that the intelligent antennas are based on the use of electromagnetic field sensor arrays, each sensor being connected to its own

transceiver, and the whole of transceivers to a process module able to duly process the signals received, or transmitted, by the single sensors. Usually, the receiver acts as "master", that is, it estimates on the azimuth plane the arrival directions of signals of the mobiles in transit in its cell and communicates this information to the transmitter that synthesises the angular openings of the antennas in the above mentioned angular directions, supplying the single sensors with replicas of a same signal, duly phase shifted among them.

While for the transmitter associated to an intelligent array antenna there is no particular realization problem, the same is not true for the implementation of the similar receiver, since the estimate of the arrival directions of useful signals is a complex operation from the computation point of view. It requires in fact an opportune processing of the module and phase information of more replicas of the radio signal received by the different sensors of the array. Said complexity derives from the fact to distinguish in the signal transduced from the array, the directions of the useful signals from those of relevant interferent signals, that is the isofrequential signals emitted by mobiles transiting in adjacent cluster cells, and the echoes due to the multiple reflections of the useful by obstacles spread over the territory, whose extent and time delay depend on the geographic environment of the cell (urban, suburban, rural environment). This information on the arrival directions is then used by the receiver to perform a spatial filtering of the N signals transduced by the array, in order to filter the useful from the different interferents.

Background Art

In the examples of base transceiver stations with intelligent antennas according to the known art, a similar discrimination of the useful from the interferents is only partially made. This does not happen for a newly conceived base transceiver station, implemented by the same applicant, whose main innovative aspects have been protected by the following relevant patent applications:

- European patent application no. 97830229.7 under the title "Communication Method for cellular telephone systems ", filed on May 16, 1997;
- Italian patent application no. MI 97A01802 under the title "Broad band transceiver for a signal consisting of a plurality of digitally modulated equispaced carriers", filed on 29th July 1997;
- Italian patent application no. MI 97A 002085 under the title "Image rejection sub-harmonic frequency converter, microstrip realized, particularly suitable to the use in mobile telephone sets", filed on 15th September 1997;

- Italian patent application no. MI 97A002086 under the title "Digital broad band transceiver for multicarrier signal", filed on 15 September 1997.
- Italian patent application under the title "Discrimination process of a useful signal by a plurality of isofrequential interferent signals received by array antennas of base transceiver stations for cellular telecommunication and relevant method"

In particular, the last mentioned application solves the problem of discrimination of the useful signal from a plurality of isofrequential interferents through a spatial filtering method, or beamforming, made on signals transduced by the array, previously submitted to a processing determining the number and the arrival directions of the waves incising on the array, distinguishing the useful from the relevant interferents.

Therefore, it is evident that in testing systems of base transceiver stations equipped with intelligent antenna, of old conception, the problem to simulate a radiofrequency scenario reflecting as precisely as possible what actually occurs in the reality, is not particularly perceived. This is a consequence of the fact that the beamforming algorithms there used do not discriminate (or do it in a rough and predictable manner) the useful signals from the relevant interferent echoes. It is then possible, and in the practice it generally occurs in the context of the known art, to use the old test equipment for base transceiver stations receivers, with omnidirectional or trisectorial antennas, apart from the simulation of the arrival directions of useful and relevant interfering echoes. Consequently, the actual test of the behaviour of the receiver complete with intelligent array antenna requires opportune test transmitters located, ad hoc, on the territory.

Summary of the Invention

A general object of the present invention is to propose a simulation process of radiofrequency scenario for the testing of radio receivers with intelligent array antenna, able to identify the direction of a useful signal from those of isofrequential interferents, irrespective of the fact that a spatial filtering is then made.

Elective object of the present invention is that to overcome the drawbacks of testing systems for receivers of base transceiver stations of cellular telephone systems of old design, and to propose a radiofrequency scenario simulation process in mobile radio environment for the testing of radio receivers of base transceiver stations with intelligent antennas, of new generation, as much realistic as possible, for the whole typology of signals which can incise on the antenna, that is: the useful signals emitted by several mobiles, the relevant echoes due to multiple reflections, the isofrequential interferents due to the reutilization of the carriers, the echoes of said

interferents, the interferents from adjacent channel, the echoes of said interferents.

To attain these objects, scope of the present invention is a simulation process of radiofrequency scenario, in particular for the testing of receivers for N sensor intelligent array antennas, able to identify the directions of useful signals from those of relevant interferents, characterized in that it includes the following phases:

a) Filling in of general tables (TAB.1, TAB.2, ..., TABK) of parameters and options defining said scenario as for a useful transmission signals, and isofrequential interferent signals, and not, having simulates arrival directions generally different from those of the relevant said useful signals;

b) conversion of said general tables in messages including, but not limited to, the description of modulating signals (SIM_D) of the transmission carriers, useful and interferents, N complex constants (SIM_BEAM_W1, SIM_BEAM_W2, ..., SIM_BEAM_WN) for each said simulated arrival direction, first and second frequency values(SIM_NCO, OL) for the conversion at intermediate frequency and radiofrequency;

c) generation and modulation of first groups of P carriers, each group consisting of one said useful or interferent carrier, and of relevant N-1 replicas, using said modulating signals, and adjusting the power level of the P carriers of said first groups;

d) multiplication of the carriers of said first groups by said complex constants corresponding to a relevant said simulated arrival direction, obtaining second groups of P modulated carriers ordered according to pre-set extent phases;

e) conversion at a relevant intermediate frequency of said second groups of modulated carriers;

f) sum of said carriers at intermediate frequency, having the same progressive order number within each said second group, obtaining P broad band signals;

g) conversion at radiofrequency of said P broad band signals, and consecutive amplification, obtaining P test signals sent to a same number of radiofrequency inputs of a said receiver to test, without antenna, as described in claim 1.

Profitably, the subject process can be used for the simulation of a radiofrequency scenario of any cellular telephone system, characterized by the reutilization of carriers. The simulated scenario can be tailored in the way time by time considered more adequate to a particular testing requirement.

According to another aspect of the invention, the simulated scenario has dynamic characteristics, obtained varying at pre-set time intervals the setting of parameters relevant to characteristic magnitudes of useful and interferent carriers

contained in said tables, which define the simulated scenario, such as for instance: level, delay, arrival direction, etc., the duration of said intervals being rather short to be comparable to the time slot employed by similar variations when occurring in a real scenario, but however sufficient to the reprogramming of the different phases of the simulated scenario.

Profitably, the simulation of the scenario includes the presence of noise, the doppler effect due to the speed of mobiles and the quick and sudden fadings of the electromagnetic field received, caused by destructive interference from multiple paths (fading of Rayleigh) or masking by obstacles of different nature encountered by the mobiles.

Since the intelligence of the receivers of a base station for mobile radio systems with intelligent antenna of new generation has the characteristics mentioned above, it results that the testing of these intelligent characteristics requires an adequate stimulation by the testing system, which shall be able to reproduce a radiofrequency scenario so richly diversified.

Therefore, further object of the invention is a testing system of receivers of a base station per mobile radio systems with intelligent array antenna, of new generation, employing the scenario simulation process scope of the present invention, as described in claim 13.

The great advantage that a similar system has, is to enable a complete and accurate testing of the receivers of the above mentioned base station, without the need of preparing sample transmitters on the territory. The system is also characterized by an exceptional flexibility in preparing the scenario considered time by time more suitable to the verification of the receiver performance compared to a particular specification standard. In fact, it is sufficient that the testing operator fills in a limited number of tables describing the scenario to simulate, afterwards, simply clicking with the mouse the same become operative in tempo real.

Brief Description of Drawings

The invention, together with further objects and advantages thereof, may be understood making reference to the following detailed description, taken in conjunction with the accompanying drawings, in which:

- fig.1 shows a quite general block diagram of the testing system scope of the present invention, connected to a device to be tested (D.U.T.);
- fig.2 shows more in detail a SIM_RF block of fig.1 belonging to the above mentioned testing system;

- fig.3 shows the SIM_RF block of fig.2 with higher detail, up to the indication of the single circuit blocks;
- fig.4 gives a representation of the directions of plane waves incising on an array antenna, usually employed during the actual operation by the device to be tested (DUT) of fig.1;
- fig.5 shows the progressive phase shifting existing among the components of a plane wave front coming from a direction φ of fig.4, on the moment the same incises on the sensors of the array;
- fig.6 shows a picture on the complex I/Q plane of the rotating vectors that represent the components of the plane wave front of fig.5; and
- fig.7 shows the tables previously stored in the permanent storage of the processor of fig.1, available to the testing operator for the setting of the parameters distinguishing a scenario to be simulated.

<u>Detailed Description</u>

Making reference to fig.1, it can be noticed a testing system of a device DUT (Device Under Test) consisting of a simulation equipment SIM_RF connected to a control processor CNTR_PC through a serial bus ET_LAN of a local network, for instance of the Ethernet type, to which also the DUT device is connected.

The SIM_RF block has N radiofrequency outputs out1, out,2, ..., outN connected, through N coaxial cables, to a same number of inputs in1, in2, ..., inN of the DUT block. Relevant radiofrequency signals RF1, RF2, ..., RFN coming out from the SIM_RF block run along said cables, and enter the DUT block. Blocks SIM_RF and DUT, as well as the personal computer CNTR_PC, are connected to the serial bus ET_LAN. More in particular, the personal computer CNTR_PC is connected to the ET_LAN bus through its own serial bus SER_PC, the DUT block through a serial bus SER_DUT, and block SIM_RF through M serial buses SER_PR1, SER_PR2, ..., SER_PRM and a M+1-th serial bus SER_LO.

In operation, the SIM_RF block is a simulation equipment governed by the personal computer CNTR_PC, and the DUT block is a receiver of a base transceiver station (BTS) for cellular telephone system of the FDMA/TDMA type, for instance GSM 900 MHz, or DCS 1800 MHz. The whole of the RF1, ..., RFN signals conforms to the selected standard that defines the radio interface. Even if not shown in the figure, the above mentioned blocks include one or more interface devices towards the local network ET_LAN.

Observing the testing configuration of the figure (test bed), we can perceive the great advantage offered by the connection in local network both of the testing system CNTR_PC, SIM_RF and of the device to test DUT. In fact, this last could send the results of the different tests directly to the computer CNTR_PC, in a completely asynchronous mode versus the flow of testing data. The control processor will avail of evaluation procedures and print of the results, and in the case of variation of input stimulations. In this way the testing will result completely automated.

Making reference to fig.2, we notice that the simulation equipment SIM_RF includes M processor modules TX_PROC1, TX_PROC2, ..., TX_PROCM; N broad band radiofrequency transmitters WB_TX1, WB_TX2, ..., WB_TXN; and a LO_CORP block generating N identical signals of local oscillator OL, reaching the transmitters WB_TX1, ..., WB_TXN.

Each TX_PROC block has N outputs for a same number of digital sequential words Cx_y reaching the relevant N parallel buses BS1, BS2, ..., BSN, where the value of index x indicates the origin from a relevant processor module m-th, while the value of index y indicates the n-th bus reached by the signal Cx_y. I bus BS1, BS2, ..., BSN are connected to an input of relevant broad band transmitters WB_TX1, WB_TX2, ..., WB_TXN identified by the same ordinal number.

In the operation, the architecture of the SIM_RF equipment shows a modularity per time division radio carrier, with a maximum of M carriers generated by M modules TX_PROC, and per antenna element, with a maximum of N elements (virtual), supplied by a same number of signals coming out from the WB_TX transmitters. Each module TX_PROC generates also the N-1 replicas of its own carrier, duly phase shifted, necessary to control the modularity per antenna element (virtual).

The processor modules TX_PROC perform the following operations, in a completely digital manner:

- acquisition of control signals by the processor CNTR_PC, as serial messages withdrawn from the bus ET_LAN;
- generation of P numeric isofrequential carriers and GMSK modulation of the same using an identical modulating signal, obtaining components in phase I and in quadrature Q of each carrier;
- multiplication of the samples of said components I and Q by relevant complex constants coming from CNTR_PC, originating "weighed" components in phase and module in order to realize beamforming, as we shall see below;
- vectorial sum of I and Q "weighed" components of each carrier, obtaining in change

digital modulated carriers GMSK;

- level control of the above mentioned modulated carriers in steps of programmable amplitude;
- control of the ramp-up and ramp-down time of the envelope of the modulated signal, at the beginning and at the end of each burst, respectively (ramp-up and ramp-down functions);
- numeric conversion at intermediate frequency of each modulated carrier, obtaining said digital words Cx_y;
- construction of N transmission digital signals of the multicarrier type at intermediate frequency, identified IF1, IF2, ..., IFN, respectively, coinciding with the buses BS1, BS2, ..., BSN, through sum of each m-th word Cx_y identified by the same index y.

Signals IF1, IF2, ..., IFN reaching the N broad band transmitters WB_TX1, WB_TX2, ..., WB_TXN, are converted to analogue by the same, typically compensating the distortion of the senx/x type, broad band filtered, and then converted at radiofrequency in test signals RF1, RF2, ..., RFN placed in a selected transmission sub-band. The N signals RF1, RF2, ..., RFN, thanks to the beamforming, are suitable to simulate up to M different arrival directions from a unique spatial point. The same directions are in fact recognized by the receiver DUT per intelligent antenna of a BTS in testing phase, and therefore without antenna, on the basis of the reciprocal phase shifting existing between the N carriers of each of the M groups of N isofrequential carriers forming the N broad band signals RF1, RF2, ..., RFN, globally conveyed in the DUT block by a same number of coaxial cables.

Fig.3 highlights with higher circuit detail what already said in the comment of fig.2; in particular it is supplied the architecture of processor modules TX_PROC and of transmitters WB_TX.

Making reference to fig. 3, in which the same elements of the previous figures are indicated with the same symbols, we notice the processor modules TX_PROC1, TX_PROC2, ..., TX_PROCM of which, only for module TX_PROC1, the internal architecture is highlighted, being the architecture of the remaining modules identical to the highlighted one. The TX_PROC1 module includes N modulators GMSK1, GMSK2, ..., GMSKN and a INTF_PC block connected, through the serial bus SER_PR1, to the serial bus ET_LAN of the local network to which all the remaining blocks TX_PROC are abutted, the LO_CORP block, as well as the personal computer CNTR_PC and the DUT block highlighted in the testing configuration (test bed) of fig.1. At output of the INTF_PC block, digital signals are present, indicated as follows:

- SIM_D, SIM_PN, and SIM_DEL directed towards all the GMSK modulators;
- N complex data SIM_BEAM_W1, SIM_BEAM_W2, ..., SIM_BEAM_WN addressed towards an input of relevant first complex digital multipliers M1, M2, ..., MN, the other input of which is reached by the components I and Q coming out from relevant GMSK modulators; and finally
- N identical digital carriers SIM_NCO addressed towards an input of relevant second digital multipliers MM1, MM2, ..., MMN, the other input of which is reached by the signals coming out from relevant first multipliers M1, M2, ..., MN (through the adders of the "weighed" I and Q components, omitted for briefness sake in the figure).

One clock input of GMSK modulators is reached also by a signal CK, used for the generation of relevant and identical digital carriers in base band.

At the output of the second multipliers MM1, MM2, ..., MMN the N signals $C1_1$, $C1_2$, ..., $C1_N$ of fig.2 are present; these last reach a first input of relevant N digital adders 1, 2, ..., N, having two inputs, also included in the TX_PROC1 block. The second input of said adders is reached by relevant sum signals of corresponding signals Cx_y generated by the remaining modules TX_PROC of the block SIM_RF. As it can be noticed in the figure, TX_PROC blocks are placed in cascade as for the adders 1 ... N, that is the output of a generic adder of a block reaches an input of the corresponding adder of the block placed downstream. Consequently, adders 1, 2, ..., N of the TX_PROC1 block, placed downstream the whole chain of blocks TX_PROC, obtain at output the digital signals at intermediate frequency IF1, IF2, ..., IFN, as cumulative sum of relevant signals Cx_y corresponding to those indicated on buses BS1, BS2, ..., BSN of fig.2. It results that the implementation of these last is actually obtained through the M groups of adders 1, 2, ..., N placed in cascade.

The N digital signals at intermediate frequency IF1, IF2, ..., IFN reach a same number of digital/analogue converters included in the relevant blocks WB_TX1, WB_TX2, ..., WB_TXN. Converted signals are duly broad band filtered, amplified, and sent to a first input of relevant mixers MX1, MX2, ..., MXN, reached also by the N identical signals of local oscillator OL coming from LO_CORP, obtaining at output N radiofrequency signals. These last are duly filtered and sent to relevant power amplifiers PA1, PA2, ..., PAN, obtaining the N signals RF1, RF2, ..., RFN present at the outputs out1, out2, ..., outN of SIM_RF.

All what said up to now concerning the operation of the SIM_RF equipment of figures 2 and 3 relates to what happens in a single time slot. This time (577 μs) is too short to complete the dialogue between CNTR_PC and SIM_RF and the required

programming of modulators GMSK by the INTF_ PC block; consequently the settings of the SIM_RF equipment, for all the time slot of the present frame possibly involved, shall be made during a frame time (4,61 ms) and shall become operative during the subsequent GSM frame.

Continuing the description of the operation of the simulation equipment SIM_RF, it is impossible to leave out of consideration the dialogue between this last and the control personal computer CNTR_PC. Before describing the methods of such a dialogue it is useful to give some theoretical clarifications on the beamforming, used in the present invention to simulate the arrival direction of useful and interferents.

Making reference to fig.4, we notice an array antenna, seen from the top, consisting of N sensors a1, a2, a3, ..., aN aligned along a straight line and separated one from the other of a distance d = $\lambda/2$, at centreband frequency of the band assigned by the particular transmission standard valid for the type of BTS to be tested. The antenna has a plane form, whose trace on the figure plane corresponds to the sensors junction line. The antenna plane is stricken by two plane waves p1 and p2 coming from two different directions, indicated with two straight lines, perpendicular to the relevant wave fronts and forming two relevant arrival angles φ and θ with the trace of the antenna plane.

Making reference to fig.5, we notice the wave front p1 on the moment it strikes the sensor a1 placed at one end of the array. From the figure it is clear that the subsequent sensors shall be stricken with ever increasing delays, consequently the modulated carrier corresponding to the plane wave p1 shall be seen at the input of the different sensors of the array like N identical modulated carriers s1(t), s2(t), ..., sN(t), phase shifted among them by ever increasing angles. All these phase shiftings are therefore in biunivocal relation with the arrival direction of p1, so that to estimate the unknown arrival direction of a generic carrier coming from a mobile, it is sufficient to measure the reciprocal phase shiftings among the signals received from single sensors, taking an ending one to determine an absolute phase reference. This is just what the block DUT performs in its actual operation. Concerning the simulation equipment SIM_RF, the dual reasoning applies, that is, starting from a direction to simulate of a test carrier, it is necessary to calculate some complex constants (beamforming coefficients) which, multiplied by N identical modulated carriers p1 give the reciprocal phase shiftings identical to those of the wave front of fig.5. It is then clear that sending this set of carriers directly downstream the array, excluding this last, we obtain the same effect as that obtained sending a carrier from a direction φ with

inserted antenna. The reasoning made for the carrier p1, whose arrival direction has to be simulated, applies to any other carrier, both useful or interferent, whose directions must be simulated them too. It is this possible to test from a unique spatial point, the laboratory one, through a simulated scenario, the characteristics of the receiver defining the intelligent behaviour of the same.

Referring to figures 5 and 6, it is now described the calculation of beamforming coefficients enabling to obtain the set of phase shifted carriers as desired. To this purpose, it is used in fig.6 a vectorial representation on plane I, Q of the modulated carriers s1(t), s2(t), ..., sN(t) of fig.5 present at the input of the single sensors a1, a2, a3, ..., aN, indicating the corresponding rotating vectors con $\mathbf{S}_1$, $\mathbf{S}_2$, $\mathbf{S}_3$, ..., $\mathbf{S}_N$. The phase absolute reference is selected arbitrarily assuming equal to zero the phase of vector $\mathbf{S}_1$. Indicating the vectors in exponential form with module *A*, and letting $\Psi = \pi \cos\varphi$, the following representation applies:

$$\mathbf{S}_1 = Ae^{j0}$$

$$\mathbf{S}_2 = Ae^{j\frac{2\pi}{\lambda}d\cos\varphi} = Ae^{j\pi\cos\varphi} = Ae^{j\Psi}$$

$$\mathbf{S}_3 = Ae^{j\frac{2\pi}{\lambda}2d\cos\varphi} = Ae^{j2\pi\cos\varphi} = Ae^{j2\Psi}$$

....

$$\mathbf{S}_N = Ae^{j\frac{2\pi}{\lambda}(N-1)d\cos\varphi} = Ae^{j(N-1)\pi\cos\varphi} = Ae^{j(N-1)\Psi}$$

The calculation of the Cartesian components of each vector is now immediate, according to the known trigonometric relations:

$$Q_1 = A$$
$$I_1 = 0$$

$$Q_2 = A\cos(\Psi) = A\cos(\pi\cos\varphi)$$
$$I_2 = A\sin(\Psi) = A\sin(\pi\cos\varphi)$$

$$Q_3 = A\cos(2\Psi) = A\cos(2\pi\cos\varphi)$$
$$I_3 = A\sin(2\Psi) = A\sin(2\pi\cos\varphi)$$

....

$$Q_N = A\cos((N-1)\Psi) = A\cos((N-1)\pi\cos\varphi)$$
$$I_N = A\sin((N-1)\Psi) = A\sin((N-1)\pi\cos\varphi)$$

The N pairs of values I and Q so obtained correspond to beamforming

coefficients SIM_BEAM_W1, SIM_BEAM_W2, ..., SIM_BEAM_WN of fig.3. In the example considered, the mathematical process described above must be repeated for the calculation of beamforming coefficients of the carrier p2; in general, M procedure for each one of the M modulated carriers, generated by the SIM_RF equipment have to be made.

It is now described the dialogue method between the personal computer CNTR_PC and the simulation equipment SIM_RF, in order to better highlight the functions of the INTF_PC block of fig.3, missing in the mentioned known art. The above mentioned dialogue occurs through sending of messages from CNTR_PC directly towards the TX_PROC units; each message is transmitted in series with a label specifying the address of the TX_PROC addressee unit and the length of the associated message, immediately followed by the message content, that is the true data.

Making reference to fig. 7, messages are automatically prepared by the processor CNTR_PC, after the testing operator has filled in a limited number of predetermined tables TAB.1, TAB.2, ..., TAB.K, which summarize the general data describing the scenario to simulate. The selection of data to enter can determine the opening of submenus containing the parameters to select for the option specified. The tabular display of SIM_RF setting data is made through windows selectable on the screen and connected among them, meaning that the modification of one or more data will affect in real time all the windows involved in said data. Clicking with the mouse, the operator opens a list of possible selectable values, for each case of the table. The operator can retrieve the tables at any moment during the testing and the possible updatings are operational in real time.

For a better comprehension of the fields given in tables of fig.7, of those that shall be included in subsequent subtables of the relevant submenus, and of those of additional tables which will clarify the content of the messages correspondingly generated, it is helpful to give just from now some brief preliminary notions on the fundamental aspects that define the radio Um interface of the system GSM, 900 MHz, to which the testing system and the device to be tested of the example shown in fig.1, make explicit reference. From these notions some operation specifications for the testing system of fig.1 will derive. As it results from the recommendations on this purpose:

- each BTS employs one or more radio carriers, each one allocated in the 900 MHz band (TX BTS : 925-960 MHz; TX MS : 880-915 MHz);

- a carrier BCCH (broadcast carrier) for the transmission, is associated to each cell, diffused to all the mobiles, of the cell characteristic information;
- each radio carrier is time divided in time slots of about 577 μs each, the transmission takes place in digital way with bit duration of about 3.6 μs;
- each time slot contains a Normal Burst of 148 bit, or an Access Burst of 88 bit;
- each Normal Burst contains a 26 bit synchronization sequence (Training sequence or middambolo), temporally positioned at the burst centre;
- the repeatitivity of the time slot occurs at frame interval of about 4.61 ms, for 8 time slot frames (TS0...TS7);
- 26 sequential frames are organized in a 120 ms multiframe; 51 sequential multiframes are organized in a 6,12 second superframe; 2048 sequential superframes are organized within an iperframe of approximately three hours and a half; such a subdivision is useful to synchronise events requiring long real times to be acquired and processed;
- the power emitted by the BTS on each time slot of each radio carrier has a level (Emission Level) depending on the distance separating BTS from MS (said distance is evaluated on the basis of the TIMING ADVANCE parameter), and level and quality of the signal received.

From the above mentioned specifications it can be noticed that up to now, recommendations concerning the behaviour of the intelligent antenna do not exist.

The BTS controls the radio interface monitoring the following parameters (updated every 480 ms):

- distance of MS from BTS, proportional to the radio signal propagation time (parameter : TIMING ADVANCE);
- level of the signal received, depending on the attenuation of radio length separating MS from BTS, within the coverage along a specified direction (parameter: RX_LEV);
- useful/interferent ratio C/I, depending on the above mentioned considerations and essentially deriving from the concept of radio resources reutilization (RX_QUAL parameter).

Based on the general notions mentioned above, some operation specifications result for the testing system of fig.1 that, as it is remembered, consists of the simulation equipment SIM_RF connected to its own control processor CNTR_PC through a serial bus ET_LAN of a local network . The above mentioned specifications are given below:

standard of the radio interface	EGSM900
subdivision in 10 MHz sub-bands TX (because a wide band digital transmitter able to cover the whole band cannot be realized up to now)	875-885 MHz 885-895 MHz 895-905 MHz 905-915 MHz
Power rated level TX for carrier	-13 dBm at the output of each WB_TX
digital control TX power level (for channel)	15 steps, 1 dB each
Number of antenna elements TX	N = 8
Maximum number of RF carriers	M = 16
No. of time slots actually assigned	Set possibility for each carrier
simulation of movement for each RF carrier	Speed setting possible (3 ÷ 250 km/h)
relative delays between RF carriers	programmable with 1 bit GSM resolution (156 bit max)
relative delays between echoes of the same carrier	programmable with 50 ns resolution (3.6 µs max)
simulation of angular direction (for each RF carrier)	programmable on 360° with 1° resolution

Going back now to the general tables of fig.7, we can notice that a given number K is foreseen (only two of them are described in detail) each one referred to a subsequent GSM frame having 4.61 ms duration. This strategy enables to gradually vary the parameters of the simulated scenario, going close to what occurs in the dynamics of a real scenario. In fact, it is known that the algorithms used by a BTS to acquire the main merit parameters of the receiver require times longer than that of a single frame. Furthermore, in the case of receiver for intelligent antenna, like that of block DUT of fig.1, the same works with adaptive algorithms performing their function at best on several subsequent frames. La sequence of K tables is cyclically repeated to enable a continuous operation of the testing system. The cyclic repetition of tests enables the results of the measures to reach a permanent steady condition after each manual updating of one or more parameters of the scenario, and demonstrates to be useful for a statistical evaluation of results. The transformation methods of the information included in tables of fig.7 in messages for the SIM_RF equipment shall be described hereafter.

The items indicated in the different cases of the general tables of fig.7 are self-explanatory and do not require additional comments. Concerning the connection of the general tables to submenus, the choice "FREQUENCY HOPPING: YES" determines the opening of a submenu with the following parameters to set:

PARAMETER	IDENTIFICATION	RANGE
n° channels RF available	N	1...50
n° selected hopping sequence	HSN	0...63
offset of the allocation index of MS	MAIO	0...N-1

The option "FADING: NO" does not determine opening of any submenu.

The option "FADING: YES" determines the opening of a submenu for the selection of one of the following known propagation models:

PROPAGATION MODEL	IDENTIFICATION
rural area	RAx (6 taps)
hilly terrain	HTx (12 taps)
reduced hilly terrain	HTx (6 taps)
urban area	TUx (12 taps)
reduced urban area	TUx (6 taps)
equalization test	EQx (6 taps)
arbitrary	CUSTOM

The selection of any propagation model (excluding CUSTOM) imposes the values of " RF level ", "delay" and "Doppler spectrum type" of the table of fig.7, which determined this choice. Access to the columns of the above mentioned table is therefore inhibited to the operator, and the values automatically included in these columns are those defined by specifications GSM 05.05 Annex C (Propagation conditions). Furthermore, rural area models, reduced hilly terrain, reduced urban area, equalization test automatically engage 6 carriers of SIM_RF; the hilly terrain, urban area models automatically engage 12 carriers of SIM_RF. The selection of the discretionary model (CUSTOM) determines the enabling of the columns "delay" and "Doppler spectrum type" and the engagement of one sole RF carrier, since the selection of the number and characteristics of possible echoes and of the possible (taps) of the model itself is up to the operator.

Once the tables of fig.7 are filled in with the data for the simulation, guided in

this by the relevant submenus, the processor CNTR_PC generates the messages instructing the processor modules TX_PROC1, TX_PROC2, ..., TX_PROCM and the block LO_CORP.

The following table lists the identification names of messages and the relevant addressee units:

TYPE OF MESSAGE	Bit No.	PC→ TX_PROC	PC→ LO_CORP
SIM_NCO (1...16)	8	x	
SIM_D (1...16)	116	x	
SIM_BEAM_Wn (1...16)	256	x	
SIM_DEL (1...16)	16	x	
BT_SIM	8	x	
P_SYNT_SIM	8		x
TSN	8	x	

All the messages having suffix (1...16) are intended as separate messages sent to the TX_PROCm module relevant to the carrier m-th (m 1 to 16). Concerning the SIM_BEAM_Wn messages, the suffix n varies from 1 to N = 8 coinciding with a generic value m to indicate N separate messages sent to the same module TX_PROCm.

The following table gives the meaning of the messages listed in the previous table:

NAME	Bit No.	MEANING
SIM_NCO	16	Programming of the RF channel transmitted in uplink
SIM_D	116	data to be transmitted in uplink (modulating signal)
SIM_BEAM_Wn	256	Module and phase of beamforming coefficients
SIM_DEL	16	delay of the simulated carrier in uplink
BT_SIM	8	training sequence code, TSC (3 bit) + selection between NORMAL or ACCESS burst (1 bit)
P_SYNT_SIM	256	programming of LO_CORP for the selection of the carrier in the assigned time slot

TSN	8	number of the time slot of the GSM frame (TSN=0...7)

The necessary procedures to process data supplied by the user and to obtain the information message in the serial format accepted by the network ET_LAN and by interface blocks INTF_PC of the simulation equipment SIM_RF are developed on CNTR_PC. Following is the list of the above mentioned procedures, specifying the procedure input information (inputs) and the information supplied by the procedure itself (outputs). The inputs are the parameters selected by the user and entered through menu and submenus. The outputs contain the messages transferred by CNTR_PC, via bus ET_LAN, to modules TX_PROC and LO_CORP.

The procedures performed by CNTR_PC for the generation of the above mentioned messages are the following:

- **frequency hopping algorithm** (see spec. GSM 05.03)
  inputs : N,HSN,MAIO $\Rightarrow$ outputs : RF channel number;
- **beamforming algorithm** (see the previous representation of figures 4, 5 and 6)
  inputs : arrival angle $\Rightarrow$ outputs : beamforming coefficients;
- **RF scenario simulation** (see spec. GSM 05.05 Annex C, propagation condition)
  inputs : standard propagation model, MS speed $\Rightarrow$ outputs : sequence of amplitude multiplication coefficients (one per frame); relative delays between echoes of the same carrier.

Making reference to fig.3, we can notice that a great part of the content of messages transferred by CNTR_PC, via ET_LAN, to the interface circuit INTF_PC, are in their turn transferred to using devices. This occurs for the contents of the messages SIM_D, TSN and SIM_DEL, transferred to modulators GMSK; for the contents of the messages SIM_BEAM_Wn, transferred to first multipliers M1, M2, ..., MN; and for the content of the message SIM_NCO, transferred to the second multipliers MM1, MM2, ..., MMN.

The contents of all the messages are updated by CNTR_PC at each 4.61 ms GSM frame, and sent according to the same intervals to the concerned units placed in local network, even if the content of a message is unchanged compared to that of the preceding frame. Consequently the concerned modules TX_PROC and LO_CORP, can process in a frame time the updated contents of the relevant messages, in order

to be able to change in real time the simulated magnitudes relevant to the modulated carriers sent to the DUT block of fig.1 in the subsequent frame.

The updating of the message content made by CNTR_PC of fig.1 at each frame, in absence of modifications introduced by the testing operator in the contents of the sequence of K tables of fig.7, and of subtables associated to the same, shall be that imposed by said sequence. On the contrary, in presence of modifications, it will reflect that of the updated sequence, starting from the point in the recurrent cycle in which the same is rendered operative. For a better understanding of the updating dynamics of messages generated by CNTR_PC, it is appropriate to underline that the compilation of the sequence of K tables of fig.7 is completely made out of line, both concerning the first drawing up and the successive modifications. Afterwards, the testing operator confirms the new version that becomes operative in real time, meaning that from that moment on, the messages sent to the network shall be generated starting from the tables of the last version, without stopping for this reason the flow of sequential messages. We can therefore conclude that while the compilation phase is completely independent from the flow of messages, the deriving updating in the content of messages, coinciding with the sending of new messages to the network, occurs in synchronous way compared to the frame interval.

From the analysis of information included in the tables of fig.7 and relevant menus, and from the typology of the deriving messages, we can deduce that availing, in whole, or in part, of the M = 16 groups of carriers <u>relevant to a same time slot</u>, each group including N = 8 replicas can be arbitrarily simulated:

- one or more useful signals;
- one or more isofrequential interferent signals (that in a real scenario are due to reutilization of the carriers in adjacent clusters) coming from directions separate from that of the relevant useful;
- one or more echoes of a useful, and/or interferent signal, (that in a real scenario are generated by multiple paths) coming from directions different from that of the useful and/or interferent;
- one or more interferents from adjacent channel, and relevant echoes; and also
- the fading effect on each one of the above mentioned signals, in non-correlated mode compared to the other signals, through multiplication of beamforming coefficients by a duly filtered pseudo-noise sequence. The operations concerning this point are directly performed by CNTR_PC through pre-processing.

The testing system of fig.1 is very flexible as for the panorama of possible scenarios to simulate, and easy to handle for the testing operator, whose task is limited to the entering of data in the general tables of fig.7. These advantages derive from the essentially digital architecture of the simulation equipment SIM_RF, which can construct N broad band digital signals at intermediate frequency IF1, ..., IFN, of the multicarrier type. Each carrier included in the broad band signals IF1, ..., IFN is characterized by a relevant content of the SIM_NCO message, which established the relevant intermediate frequency; therefore the simulation of several isofrequential interferents engages several modules TX_PROC to which SIM_NCO messages having identical content are sent.

Embodiments

In the applicant's opinion, the testing system described in the example, with particular reference to fig.3, is the best mode to implement the invention (best mode), both for the flexibility allowed by such an architecture, and for the limited costs of a mainly digital realization.

However, there is a further implementation possibility, differing from the previous one in that it employs narrow band transmitters, in harmony with the architecture of the major part of base transceiver stations presently in operation. To the purposes of a more complete coverage of inventive aspects we must also describe this embodiment of testing system (without appending appropriate figures). Similarly to what previously done, the system embodiment applies the teachings of an embodiment of the process.

Therefore, an additional object of the invention is a process embodiment including phases a'), b'), c'), d'), identical to those bearing the same name of the process already object of the invention, and subsequent phases e'), f'), g') more properly concerning the embodiment. This last applies therefore starting from the second groups of N modulated carriers, multiplied by the beamforming coefficients. Contrarily to what said for the main process, the embodiment foresees a conversion at a unique intermediate frequency identical for all the carrier groups, to which a subsequent conversion to a second intermediate frequency is recommended to simplify the radiofrequency filtering. The frequency distinction among the various second groups of carriers is assigned to the radiofrequency conversion of the same, through relevant signals of local oscillator. The N test signals RF1, RF2, ..., RFN, to send to the receiver, are obtained amplifying and summing up among them (combining broad band RF) the radiofrequency carriers having the same progressive

order number within each second group.

For what said above, a further object of the invention is an embodiment including the same means of the system already scope of invention that enabled to obtain in base band the second groups of N digital carriers ordered according to gradual increasing phases. To the above mentioned means, the following one characteristic of the embodiment are added:

- digital/analogue conversion means of said second groups of N carriers and filtering means in channel band;
- conversion and filtering means at intermediate frequency of said second groups of carriers;
- conversion and filtering means at a relevant radiofrequency of said second groups of carriers at intermediate frequency, and subsequent channel band amplification means;
- radiofrequency combining means, that is of reciprocal broad band coupling, of said carriers amplified at channel band, having the same progressive order number within each said second group, obtaining N test signals RF1, RF2, ..., RFN that reach N radiofrequency outputs of a scenario simulation equipment including the above listed means;
- a whole of N coaxial cables, or equivalent means, connecting said N radiofrequency outputs to a same number of inputs (in1, in2, ..., inN) of the receiver DUT, without antenna.

Concerning the exchange of messages between the control processor CNTR_PC and the scenario simulation equipment of the embodiment, through the interface means INTF_PC and LO_CORP, also included in said equipment, the message typology remains the same of the example, paying attention to select one single frequency value expressing the content of the message SIM_NCO, and as many frequency values OL, different among them, as are required to simulate non-isofrequential signals.

In the testing system according to the variant, the analogue part, more expensive, prevails on the digital one. In fact, to completely take advantage of the configuration of $M = 16$ carriers and relevant $N = 8$ replicas, totalling $16 \times 8 = 148$ generated signals, it should be required a same number of radiofrequency amplifiers and relevant couplers!

<u>Generalizations</u>

The simulation system of the example lends itself to some generalizations that configure the invention applicable to other mobile radio systems with system setting different from the FDMA/TDMA one. For instance, as far as the invention is concerned, the TDMA aspect is not strictly necessary and, strictly speaking, also the FDMA aspect can be not considered, since for the simulation of a minimum, but realistic scenario, one sole carrier is sufficient with its isofrequential interferents. As for the invention, if we want to leave out of consideration the FDMA/TDMA architecture of the embodiment, we must be considered the dynamic characteristic of the simulated scenario which up to now was given by the updating of the significant parameters of the same at 4.61 ms interval of the GSM frame. This time slot is a good compromise between the need to avail of a processing time sufficient to the generation of configuration messages of the scenario, to their transfer on local network, and to the programming of the addressee units of the content of the same, and that to be able to simulate a realistic time slot in which the variations indicated by the succession of parameters, correspond to a same variation of the same magnitudes, but referred to phenomena which in the real context comprise the involved carriers.

From the above we can conclude that it is possible to employ the present invention to simulate the radiofrequency scenario in the testing of a base transceiver station of a cellular telephone system of the analogue type with FDMA philosophy, for instance TACS. In this case, whenever the processing times enable it, it is possible to update the scenario parameters with interval lower than 4.61 ms of the example, reaching a finer accuracy in the dynamic simulation.

From what said up to now we can conclude that, without departing from the fieldsd of the invention, the same can have further applications, in addition to those foreseen for cellular telephone systems. For instance, it is possible to use the invention in all the cases where it is necessary to test receivers for intelligent array antennas employing beamforming algorithms, but leaving out of consideration the basic philosophy of all the mobile radio telephone systems, and therefore the fact that all the interferents are caused by the reutilization of the same carriers in a territory subdivided in cells of adjacent clusters.

Possible applications of the invention in this way could be forecast in the satellite sector. Other possible applications of the invention in sectors different from the mobile radio telecommunication one, could be predicted in the radar sector.

Therefore, while some embodiments of the present invention have been shown and described, it should be understood that the present invention is not

limited thereto since other embodiments may be made by those skilled in the art without departing from the scope thereof. It is thus contemplated that the present invention encompasses any and all such embodiments covered by the following claims.

CLAIMS

1. Simulation process of radiofrequency scenario, in particular for the testing of receivers for intelligent array antennas at N sensors able to identify the directions of useful signals from those of relevant interferents, characterized in that it includes the following phases:

a) compilation of general tables (TAB.1, TAB.2, ..., TABK) of parameters and options defining said scenario concerning useful transmission signals, and isofrequential interferent signals, and not, having simulated arrival directions generally different from those of the relevant said useful signals;

b) conversion of said general tables in messages including, but not limited to, the description of modulating signals (SIM_D) of the transmission carriers, useful and interferents, N complex constants (SIM_BEAM_W1, SIM_BEAM_W2, ..., SIM_BEAM_WN) for each one of said simulated arrival direction, first and second frequency values(SIM_NCO, OL) for the conversion to intermediate frequency and radiofrequency;

c) generation and modulation of first groups of P carriers, each group consisting of one said useful, or interferent carrier, and of relevant N-1 replicas, using said modulating signals, and adjustment of the power level of the P carriers of said first groups;

d) multiplication of the carriers of said first groups for said complex constants corresponding to a relevant said simulated arrival direction, obtaining second groups of P carriers modulate ordered according to gradually increasing phases;

e) conversion at a relevant intermediate frequency (SIM_NCO) of said second groups of modulated carriers;

f) sum of said carriers at intermediate frequency ($C1_1$, $C1_2$, ..., $C1_N$) having the same progressive order number within each said second group, obtaining N broad band signals (IF1, IF2, ..., IFN);

g) conversion at radiofrequency of said N broad band signals (IF1, IF2, ..., IFN), and subsequent amplification, obtaining N test signals (RF1, RF2, ..., RFN) sent to a same number of radiofrequency inputs (in1, in2, ..., inN) of a said receiver to test (DUT), without antenna.

2. Simulation process of radiofrequency scenario, in particular for the testing of receivers for N sensor intelligent array antennas able to identify the directions of useful signals from those of relevant interferents, characterized in that it includes the following phases:

a') 'filling in of general tables (TAB.1, TAB.2, ..., TABK) of parameters and options

defining said scenario concerning a useful transmission signals, and isofrequential interferent signals, and not, having simulated arrival directions generally different from those of said relevant useful signals;

b') conversion of said general tables in messages including, but not limited to, the description of modulating signals (SIM_D) of the transmission carriers, useful and interferent signals, N complex constants (SIM_BEAM_W1, SIM_BEAM_W2, ..., SIM_BEAM_WN) for each said simulated arrival direction, first and second frequency values(SIM_NCO, OL) for the conversion at intermediate frequency and at radiofrequency;

c') generation and modulation of first groups of P carriers, each group consisting of a said useful, or interferent carrier, and of relevant N-1 replicas, employing said modulating signals, and adjustment of the power level of the P carriers of said first groups;

d') multiplication of the carriers of said first groups for said complex constants corresponding to a relevant said simulated arrival direction, obtaining second groups of P modulated carriers ordered according to gradual increasing phases;

e') conversion at intermediate frequency of said second groups of modulated carriers;

f') conversion to a relevant radiofrequency of said second groups of carriers at intermediate frequency, filtering and amplification at channel band;

g') 'sum of said carriers converted at a relevant radiofrequency having the same progressive number within each said second group, obtaining N test signals (RF1, RF2, ..., RFN) sent to a same number of radiofrequency inputs (in1, in2, ..., inN) of one said receiver to test (DUT), without antenna.

3. Simulation process according to claim 1, or 2, characterized in that said general tables (TAB.1, TAB.2, ..., TABK) compiled in said phase a) are organized in a sequence of K tables cyclically repeated.

4. Simulation process according to claim 3, characterized in that said phases b), c), d), e), f), g), or as an alternative b'), c'), d'), e'), f'), g'), form a sequence repeated at sequential time interval of the same duration, using time by time said messages obtained converting a new general table of said cyclic sequence, thus giving dynamic and recurrent characteristics to said simulated scenario.

5. Simulation process according to claim 4, characterized in that said duration is such that the variation speed of the contents of said messages can be compared to the one that can be detected in the corresponding said parameters of a real scenario.

6. Simulation process according to claim 5, characterized in that said duration in equal to, or lower than 4.61 ms.

7. Simulation process according to any claim 4 through 6, characterized in that said general tables (TAB.1, TAB.2, ..., TABK) filled in during said phase a), or a'), are updated during the testing, and of the corresponding updated messages are generated in synchronous mode compared to said sequential time intervals.

8. Simulation process according to claim 1, or 2, characterized in that it included additional acquisition phases of the results of said testing, in asynchronous mode compared to said sequential time intervals.

9. Simulation process according to claim 1, or 2, characterized in that the selection of some of said options of said general tables (TAB.1, TAB.2, ..., TABK) involves the compilation of relevant subtables containing additional parameters to select for the specified option.

10. Simulation process according to any of the previous claims, characterized in that said radiofrequency scenario is referred to a cellular telephone system characterized by the reutilization of identical carriers in cells of adjacent cluster.

11. Simulation process according to claim 10, characterized in that said carriers are time division employed, and said duration corresponds to a frame time.

12. Simulation process according to claims 10, or 11, characterized in that said general tables (TAB.1, TAB.2, ..., TABK) include also parameters that take into account the presence of noise, the doppler effect due to the speed of the mobiles, and the quick and sudden fading of the electromagnetic field received, caused by multiple paths destructive interference or by masking by obstacles encountered by mobiles in movement.

13. Testing system of receivers for intelligent array antennas at N sensors able to identify the directions of useful signals from those of relevant interferents, characterized in that it includes:

- a control processor (CNTR_PC);
- interface means (INTF_PC, LO_CORP) towards said processor (CNTR_PC), that receive from said messages, including, but not limited to, the description of modulating signals (SIM_D) of the transmission carriers, useful and interferents, N complex constants (SIM_BEAM_W1, SIM_BEAM_W2, ..., SIM_BEAM_WN) for each said simulated arrival direction, first and second frequency values (SIM_NCO, OL) for the conversion at intermediate frequency and at radiofrequency;
- generation and modulation means(GMSK1, GMSK2, ..., GMSKN) of first groups of N

digital carriers, each group consisting of a useful, or interferent carrier, and of relevant N-1 replicas;

- multipliers digital means (M1, M2, ..., MN) of the carriers of said first groups for said complex constants (SIM_BEAM_W1, SIM_BEAM_W2, ..., SIM_BEAM_WN) corresponding to a said simulated arrival direction, obtaining second groups of N carriers modulate ordered according to gradual increasing phases;
- digital conversion means (MM1, MM2, ..., MMN) at a relevant intermediate frequency (SIM_NCO) of said second groups of carriers;
- digital adding means (1, 2, ..., N) of said carriers converted at a relevant frequency intermediate ($C1_1$, $C1_2$, ..., $C1_N$) having the same progressive number within each said second group, to obtain N broad band digital signals (IF1, IF2, ..., IFN);
- digital/analogue conversion means (D/A) of said N broad band digital signals (IF1, IF2, ..., IFN) and broad band filtering means;
- radiofrequency conversion and filtering means (LO_CORP, MX1, MX2, ..., MXN) of said N broad band filtered signals (IF1, IF2, ..., IFN);
- broad band amplification means (PA1, PA2, ..., PAN) of said radiofrequency signals, to obtain N test signals (RF1, RF2, ..., RFN) reaching N radiofrequency outputs (out1, out,2, ..., outN) of a scenario simulation equipment (SIM_RF) including the above mentioned means;
- a whole of N coaxial cables, or equivalent means, connecting said N radiofrequency outputs to a same number of inputs (in1, in2, ..., inN) of a said receiver (DUT), without antenna.

14. Testing system of receivers for intelligent array antennas at N sensors able to identify the directions of useful signals from those of relevant interferents, characterized in that it includes:

- a control processor (CNTR_PC);
- interface means(INTF_PC, LO_CORP) towards said processor (CNTR_PC) that receive from these messages including, but not limited to, the description of modulating signals (SIM_D) of the, useful and interferents transmission carriers, N complex constants (SIM_BEAM_W1, SIM_BEAM_W2, ..., SIM_BEAM_WN) for each said simulated arrival direction, first and second frequency values(SIM_NCO, OL) for the conversion at intermediate frequency and at radiofrequency;
- generation and modulation means (GMSK1, GMSK2, ..., GMSKN) of first groups of P digital carriers, each group consisting of a useful, or interferent carrier, and of relevant

N-1 replicas;

- multiplier digital means (M1, M2, ..., MN) of the carriers of said first groups by said complex constants (SIM_BEAM_W1, SIM_BEAM_W2, ..., SIM_BEAM_WN) corresponding to one said simulated arrival direction, obtaining second groups of P modulated carriers ordered according to gradual increasing phases;
- conversion digital/analogue means (D/A) of said second groups of P carriers and filtering means in channel band;
- conversion and filtering means a intermediate frequency of said second groups of carriers;
- conversion and filtering means at a relevant radiofrequency of said second groups of carriers at intermediate frequency, and successive channel band amplification means;
- reciprocal coupling means at radiofrequency, broad band, of said carriers amplified at channel band, having the same progressive order number within each said second group, obtaining N test signals (RF1, RF2, ..., RFN) that reach N outputs a radiofrequency (out1, out,2, ..., outN) of a scenario simulation equipment including the means listed above;
- a whole of N coaxial cables, or equivalent means, connecting said N radiofrequency outputs to a same number of inputs (in1, in2, ..., inN) of a said receiver (DUT), without antenna.

15. Testing system according to claim 13, or 14, characterized in that said control processor (CNTR_PC) transfers to said interface means (INTF_PC, LO_CORP) said control messages (SIM_D, SIM_BEAM_W1, SIM_BEAM_W2, ..., SIM_BEAM_WN SIM_NCO, OL) ad sequential time intervals of identical duration .

16. Testing system according to claim 15, characterized in that said duration is such for which the variation speed of the contents of said messages can be compared to that which can be detected in corresponding parameters of a real scenario.

17. Testing system according to claim 15, or 16, characterized in that said messages are obtained from the conversion of general tables (TAB.1, TAB.2, ..., TABK) of parameters and options defining said simulated scenario, stored by said control processor (CNTR_PC).

18. Testing system according to claim 17, characterized in that said general tables (TAB.1, TAB.2, ..., TABK) are organized in a sequence of K tables cyclically repeated.

19. Testing system according to claim 18, characterized in that said duration is equal to or lower than 4.61 ms.

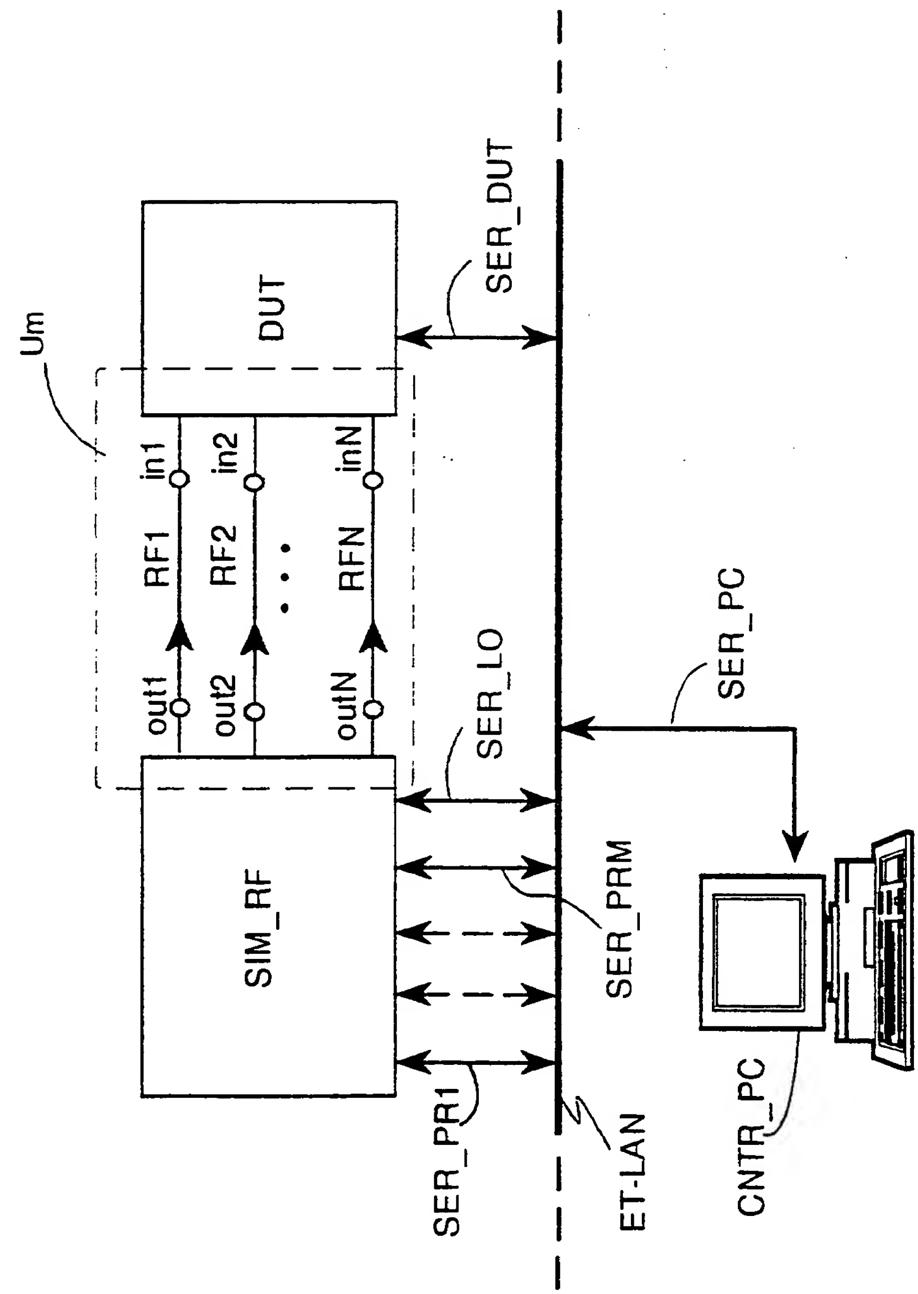
20. Testing system according to any claim 17 through 19, characterized in that said general tables (TAB.1, TAB.2, ..., TABK) are filled in before the testing and updated during the testing, and of the corresponding updated messages are generated in synchronous mode compared to said sequential time intervals.

21. Testing system according to claim 13, or 14, characterized in that said control processor (CNTR_PC), said scenario simulation equipment (SIM_RF), and said receiver (DUT) are connected to the bus (ET_LAN) of a local network; said messages are serial, and said receiver to test transfers to said control processor (CNTR_PC) the results of the testing.

22. Testing system according to any claim 13 to 21, characterized in that said scenario a radiofrequency is referred to a cellular telephone system characterized by the reutilization of identical carriers in cells of adjacent clusters.

23. Testing system according to claim 22, characterized in that said carriers are time division employed, and said duration corresponds to a frame time.

24. Testing system according to claim 22, or 23, characterized in that said general tables (TAB.1, TAB.2, ..., TABK) include also parameters to simulate the presence of noise, the doppler effect due to the speed of the mobiles, and the quick and sudden fadings of the electromagnetic field received, caused by destructive interference by multiple paths or by masking by obstacles encountered by the mobiles in movement.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in1
in2
inN
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RF2
RFN
out1
out2
outN
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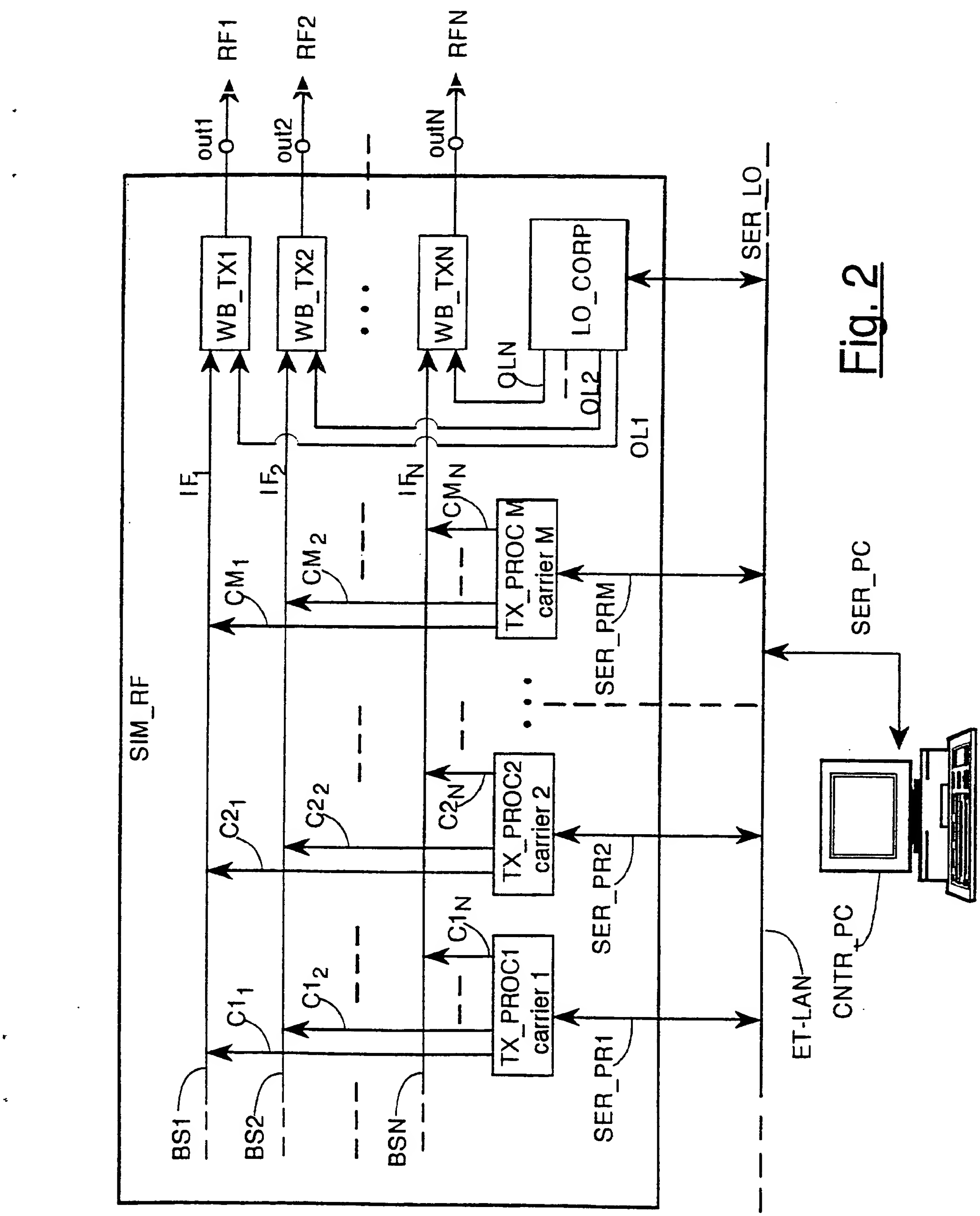
SER_LO
SER_PC
SER_PRM
SER_PR1
ET-LAN
CNTR_PC

Fig. 1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SER_LO
IF1
IF2
IFN
CMN
CM2
CM1
TX_PROC M
carrier M
SER_PRM
SER_PC
C21
C22
C2N
TX_PROC2
carrier 2
SER_PR2
C11
C12
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carrier 1
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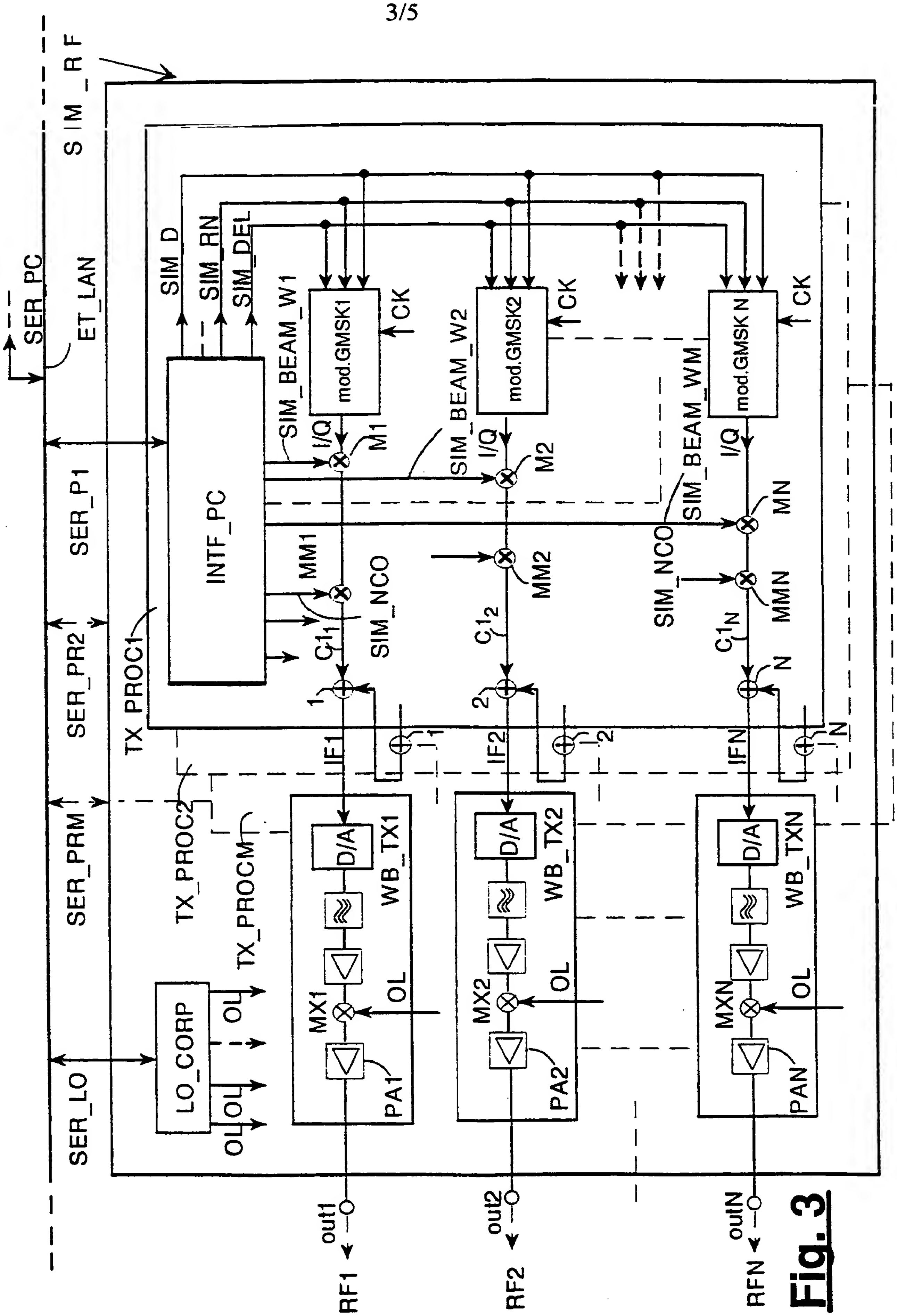
BS1
BS2
BSN
ET-LAN
CNTR_PC

Fig. 2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SIM_RN
SIM_DEL
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SIM_BEAM_W2
SIM_BEAM_WM
SIM_BEAM_
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mod.GMSK2
mod.GMSK N
CK
I/Q
M1
M2
MN
SER_P1
INTF_PC
MM1
MM2
MMN
SIM_NCO
SER_PR2
TX_PROC1
TX_PROC2
TX_PROCM
SER_PRM
IF1
IF2
IFN
D/A
WB_TX1
WB_TX2
WB_TXN
OL
MX1
MX2
MXN
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PA2
PAN
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SER_LO
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out2
outN
RF1
RF2
RFN

Fig. 3

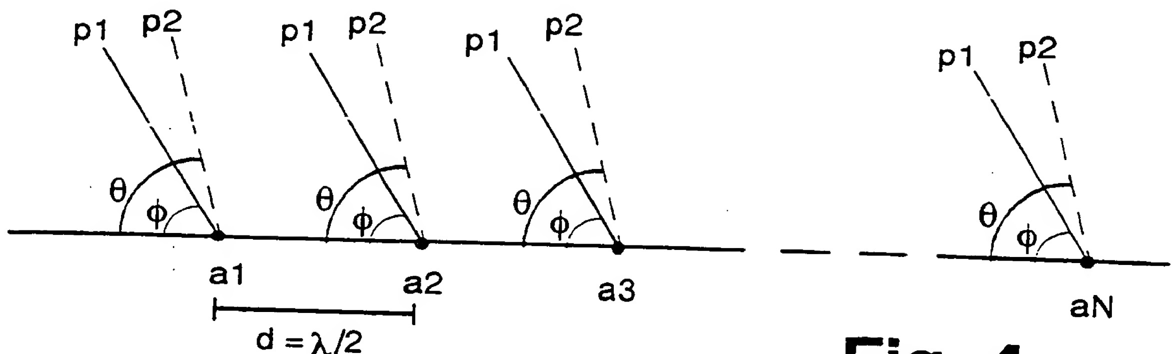

Fig. 4

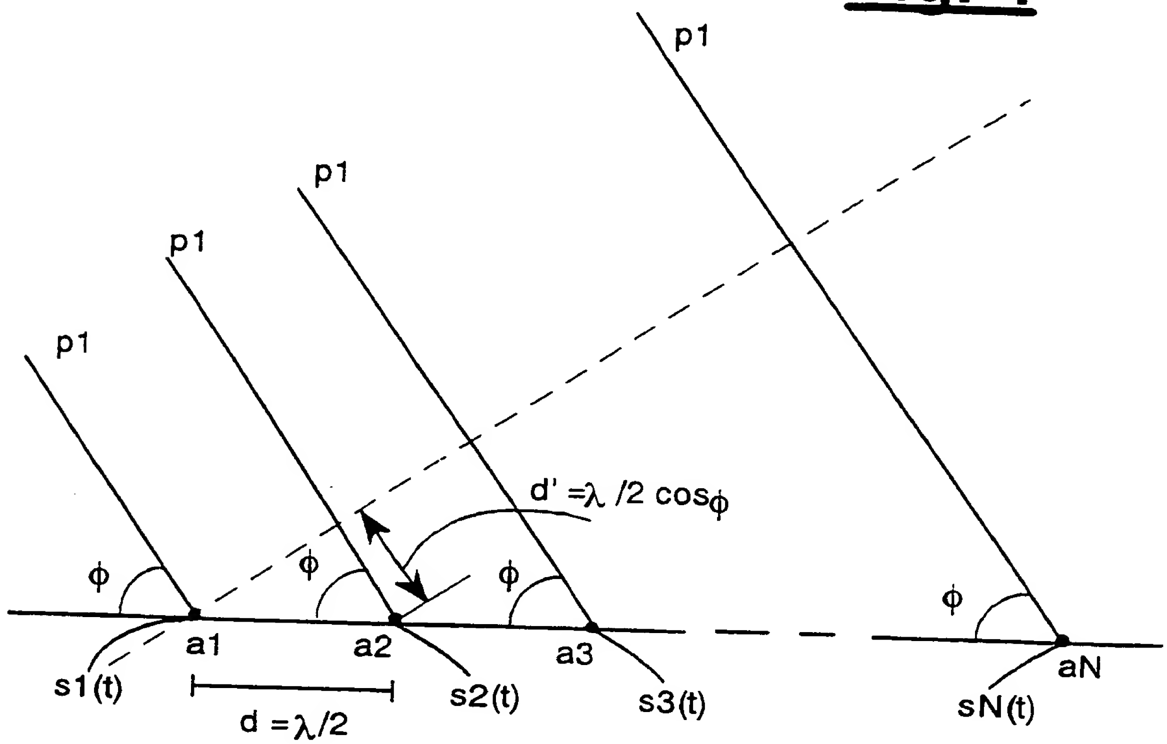

Fig. 5

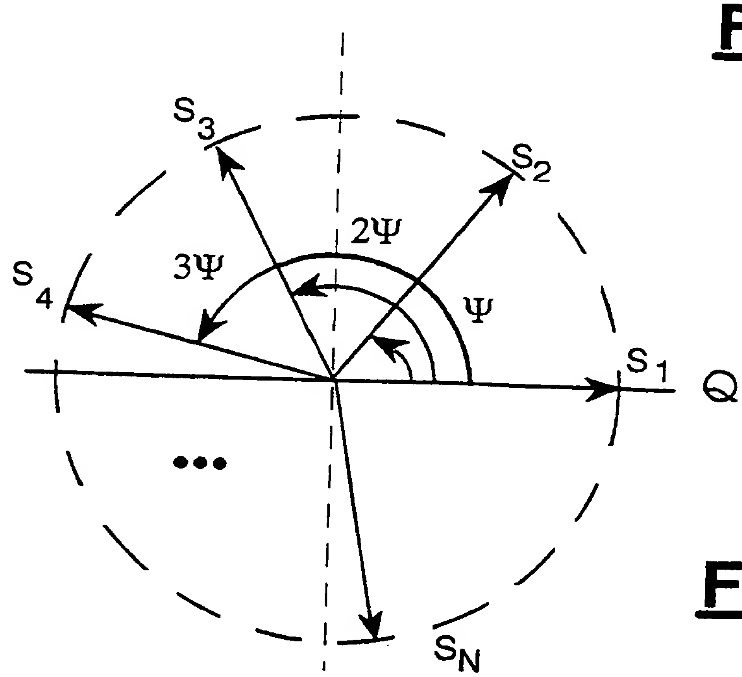

Fig. 6

Trama GSM n. 1

Numero	Periferica di destinazione	tipo di canale	frequency hopping	livello RF	numero canale RF	direzione d'arrivo	tipo di fading	ritardo	Doppler spectrum type	velocità di MS
1	TX_PROC#1	portante utile	NO	-50 dBm	126	60°	NO	0 μs	-	0 km/h
2	TX_PROC#2	eco utile	NO	-56 dBm	126	62°	NO	1 μs	-	0 km/h
3	TX_PROC#3	interferente	SI	-60 dBm	126	70°	NO	56 μs	-	0 km/h
...										
16	TX_PROC#16	eco interferente	NO	-70 dBm	127	55°	SI	117 μs	CLASS	50 km/h

Tab 1

Trama GSM n. 2

Numero	Periferica di destinazione	tipo di canale	frequency hopping	livello RF	numero canale RF	direzione d'arrivo	tipo di fading	ritardo	Doppler spectrum type	velocità di MS
1	TX_PROC#1	portante utile	NO	-49 dBm	126	61°	NO	0 μs	-	0 km/h
2	TX_PROC#2	eco utile	NO	-58 dBm	126	63°	NO	1 μs	-	0 km/h
3	TX_PROC#3	interferente	SI	-60 dBm	103	70°	NO	56 μs	-	0 km/h
...										
16	TX_PROC#16	eco interferente	NO	-68 dBm	127	54°	SI	117 μs	CLASS	50 km/h

Tab 2

Trama GSM n. k

Tab. k

Fig. 7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 98/07762

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B17/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 539 772 A (FASULO II ALBERT J ET AL) 23 July 1996 see column 4, line 17 - column 6, line 17; figures 2,3A,3B see column 9, line 66 - column 10, line 32 ---	1,2,13, 14
A	DIOURIS J F ET AL: "MULTISENSOR RECEIVER FOR MOBILE COMMUNICATIONS: AN EXPERIMENTAL STUDY" RECORD OF THE ASILOMAR CONFERENCE ON SIGNALS, SYSTEMS AND COMPUTERS, PACIFIC GROVE, OCT. 30 - NOV. 2, 1994, vol. 1, no. CONF. 28, 30 October 1994, pages 465-469, XP000533603 INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS see the whole document -----	1,2,13, 14

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 April 1999	27/04/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Wanzeele, R

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 98/07762

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5539772 A	23-07-1996	NONE	

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only
PCT/EP 98 / 07762
International Application No.
26 NOV 1998 (26 11 1998)
International Filing Date
EUROPEAN PATENT OFFICE PCT INTERNATIONAL APPLICATION
Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)* DB 744 PCT

Box No. I TITLE OF INVENTION

Simulation process of radiofrequency scenario in radio mobile environment and testing system employing said process

Box No. II APPLICANT

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

ITALTEL SPA
Via A. di Tocqueville, 13
20154 MILANO
ITALY

☐ This person is also inventor.

Telephone No. +39.02.43887701

Facsimile No. +39.02.43887703

Teleprinter No. 314840 SITELE I

State *(that is, country)* of nationality: IT

State *(that is, country)* of residence: IT

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

DONATI MARCELLO
VIA BAZZINI, 9
20131 MILANO
ITALY

This person is:

☐ applicant only

☒ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: IT

State *(that is, country)* of residence: IT

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

GIUSTINI DELIO
C/O ITALTEL SPA
CASCINA CASTELLETTO
20019 SETTIMO MILANESE
ITALY

Telephone No. +39.02.43887701

Facsimile No. +39.02.43887703

Teleprinter No. 314840 SITELE I

☐ **Adress for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Sheet No. 2 ......

Continuation of Box No. III FURTHER APPLICANTS AND/OR (FURTHER) INVENTORS

If none of the following sub-boxes is used, this sheet should not be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

POLITI MARCO
VIA MOSCOVA, 58
20121 MILANO
ITALY

This person is:

☐ applicant only

☒ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: IT

State *(that is, country)* of residence: IT

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

☐ applicant only

☐ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

☐ applicant only

☐ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

☐ applicant only

☐ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

Sheet No. 3......

Box No. V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked)*:

Regional Patent

- ☐ **AP** **ARIPO Patent:** **GH** Ghana, **GM** Gambia, **KE** Kenya, **LS** Lesotho, **MW** Malawi, **SD** Sudan, **SZ** Swaziland, **UG** Uganda, **ZW** Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT
- ☐ **EA** **Eurasian Patent:** **AM** Armenia, **AZ** Azerbaijan, **BY** Belarus, **KG** Kyrgyzstan, **KZ** Kazakhstan, **MD** Republic of Moldova, **RU** Russian Federation, **TJ** Tajikistan, **TM** Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT
- ☒ **EP** **European Patent:** **AT** Austria, **BE** Belgium, **CH and LI** Switzerland and Liechtenstein, **CY** Cyprus, **DE** Germany, **DK** Denmark, **ES** Spain, **FI** Finland, **FR** France, **GB** United Kingdom, **GR** Greece, **IE** Ireland, **IT** Italy, **LU** Luxembourg, **MC** Monaco, **NL** Netherlands, **PT** Portugal, **SE** Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT
- ☐ **OA** **OAPI Patent:** **BF** Burkina Faso, **BJ** Benin, **CF** Central African Republic, **CG** Congo, **CI** Côte d'Ivoire, **CM** Cameroon, **GA** Gabon, **GN** Guinea, **ML** Mali, **MR** Mauritania, **NE** Niger, **SN** Senegal, **TD** Chad, **TG** Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* ....

National Patent *(if other kind of protection or treatment desired, specify on dotted line)*:

- ☐ **AL** Albania
- ☐ **AM** Armenia
- ☐ **AT** Austria
- ☐ **AU** Australia
- ☐ **AZ** Azerbaijan
- ☐ **BA** Bosnia and Herzegovina
- ☐ **BB** Barbados
- ☐ **BG** Bulgaria
- ☐ **BR** Brazil
- ☐ **BY** Belarus
- ☒ **CA** Canada
- ☐ **CH and LI** Switzerland and Liechtenstein
- ☐ **CN** China
- ☐ **CU** Cuba
- ☐ **CZ** Czech Republic
- ☐ **DE** Germany
- ☐ **DK** Denmark
- ☐ **EE** Estonia
- ☐ **ES** Spain
- ☐ **FI** Finland
- ☐ **GB** United Kingdom
- ☐ **GE** Georgia
- ☐ **GH** Ghana
- ☐ **GM** Gambia
- ☐ **GW** Guinea-Bissau
- ☐ **HR** Croatia
- ☐ **HU** Hungary
- ☐ **ID** Indonesia
- ☐ **IL** Israel
- ☐ **IS** Iceland
- ☐ **JP** Japan
- ☐ **KE** Kenya
- ☐ **KG** Kyrgyzstan
- ☐ **KP** Democratic People's Republic of Korea
- ☐ **KR** Republic of Korea
- ☐ **KZ** Kazakhstan
- ☐ **LC** Saint Lucia
- ☐ **LK** Sri Lanka
- ☐ **LR** Liberia
- ☐ **LS** Lesotho
- ☐ **LT** Lithuania
- ☐ **LU** Luxembourg
- ☐ **LV** Latvia
- ☐ **MD** Republic of Moldova
- ☐ **MG** Madagascar
- ☐ **MK** The former Yugoslav Republic of Macedonia
- ☐ **MN** Mongolia
- ☐ **MW** Malawi
- ☐ **MX** Mexico
- ☐ **NO** Norway
- ☐ **NZ** New Zealand
- ☐ **PL** Poland
- ☐ **PT** Portugal
- ☐ **RO** Romania
- ☐ **RU** Russian Federation
- ☐ **SD** Sudan
- ☐ **SE** Sweden
- ☐ **SG** Singapore
- ☐ **SI** Slovenia
- ☐ **SK** Slovakia
- ☐ **SL** Sierra Leone
- ☐ **TJ** Tajikistan
- ☐ **TM** Turkmenistan
- ☐ **TR** Turkey
- ☐ **TT** Trinidad and Tobago
- ☐ **UA** Ukraine
- ☐ **UG** Uganda
- ☒ **US** United States of America
- ☐ **UZ** Uzbekistan
- ☐ **VN** Viet Nam
- ☐ **YU** Yugoslavia
- ☐ **ZW** Zimbabwe

Check-boxes reserved for designating States (for the purposes of a national patent) which have become party to the PCT after issuance of this sheet:

- ☐ ....
- ☐ ....

Precautionary Designation Statement: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation of a designation consists of the filing of a notice specifying that designation and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.)*

Box No. VI PRIORITY CLAIM ☐ Further priority claims are indicated in the Supplemental Box.

Filing date of earlier application *(day/month/year)*	Number of earlier application	Where earlier application is: national application: country	regional application:* regional Office	international application: receiving Office
item (1) (19. 12. 97) 19 December 1997	MI97A002826	IT[ALY]		
item (2)				
item (3)				

☐ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office)* identified above as item(s):

* *Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.*

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used):*

ISA /

Request to use results of earlier search; reference to that search *(if an earlier search has been carried out by or requested from the International Searching Authority):*

Date *(day/month/year)* Number Country *(or regional Office)*

Box No. VIII CHECK LIST; LANGUAGE OF FILING

This international application contains the following **number of sheets**:

request	: 04
description (excluding sequence listing part)	: 22
claims	: 06
abstract	: 01
drawings	: 05
sequence listing part of description	:
Total number of sheets	: 38

This international application is **accompanied by** the item(s) marked below:

1. ☒ fee calculation sheet
2. ☒ separate signed power of attorney
3. ☒ copy of general power of attorney; reference number, if any: 25928
4. ☐ statement explaining lack of signature
5. ☒ priority document(s) identified in Box No. VI as item(s): 1 + English translation
6. ☒ translation of international application into (language): ENGLISH
7. ☐ separate indications concerning deposited microorganism or other biological material
8. ☐ nucleotide and/or amino acid sequence listing in computer readable form
9. ☐ other *(specify)*:

Figure of the drawings which should accompany the abstract: FIG. 1

Language of filing of the international application: ENGLISH

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

Milan, 18 November 1998

Delio GIUSTINI
G.A. 25928

For receiving Office use only

1. Date of actual receipt of the purported international application:	26 NOV 1998 (26. 11. 1998)
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:	
4. Date of timely receipt of the required corrections under PCT Article 11(2):	
5. International Searching Authority (if two or more are competent): ISA /	6. ☐ Transmittal of search copy delayed until search fee is paid.

2. Drawings: ☒ received: ☐ not received:

For International Bureau use only

Date of receipt of the record copy by the International Bureau:

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

GIUSTINI, D.
ITALTEL SPA
Cascina Castelletto
I-20019 Settimo Milanese
ITALIE

PCT

NOTIFICATION OF TRANSMITTAL OF
THE INTERNATIONAL PRELIMINARY
EXAMINATION REPORT

(PCT Rule 71.1)

Date of mailing *(day/month/year)*	24.03.00

Applicant's or agent's file reference	
DB 744 PCT	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP98/07762	26/11/1998	19/12/1997

Applicant
ITALTEL SPA et al.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

   The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

   Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

   For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Teschauer, B Tel.+49 89 2399-8231

3

REC'D 28 MARS 2000
WIPO

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
DB 744 PCT		
International application No. PCT/EP98/07762	International filing date *(day/month/year)* 26/11/1998	Priority date *(day/month/year)* 19/12/1997
International Patent Classification (IPC) or national classification and IPC H04B17/00		
Applicant ITALTEL SPA et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 7 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 26 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
06/07/1999	
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Koch, B Telephone No. +49 89 2399 7303

I. Basis of the report

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

Description, pages:

21,22	as originally filed			
1-20	as received on	04/02/2000	with letter of	02/02/2000

Claims, No.:

1-21	as received on	04/02/2000	with letter of	02/02/2000

awings, sheets:

1/5,2/5,4/5,5/5	as originally filed			
3/5	as received on	04/02/2000	with letter of	02/02/2000

2. The amendments have resulted in the cancellation of:

☐ the description, pages:
☐ the claims, Nos.:
☐ the drawings, sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

see separate sheet

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-21
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-21
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-21
	No:	Claims	

2. Citations and explanations

see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Re Item I
Basis of the report

1. Since the amendments filed by telefax of 02.02.1999 introduce subject-matter which extends beyond the content of the application as filed, contrary to Article 34(2)(b) PCT, the report has been established as if the omitted features (see Re Item VII) or corresponding features were still present in the claims.

Re Item V
Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. **Field:**
The invention relates to the field of test systems for telecommunication equipment and more particular to a simulation apparatus and method of a mobile radiofrequency scenario employing N-element array antennas.

2. **Prior Art:**
Closest prior art is D1 (US-A-5 539 772). It discloses an apparatus and method for verifying performance of RF receivers, especially DQPSK signals for satellite applications.

3. **Problem:**
The invention solves the problem of providing an apparatus/method for testing receivers of base stations with N-element array antennas for mobile communications.

4. **Solution:**
The Problem is solved by a method (claim 1) and an apparatus (claim 12) for simulating a mobile radio environment. On the module TX_PROC (cf. figure 3), messages controlled from a PC(CNTR_PC) are passed to GMSK modulators (GMSK1-GMSKN) via an interface (INTF_PC). The output of the modulators represents useful and interferent transmission carriers. This signal is multiplied (M1-MN) with complex constants (SIM_BEAM_W1-SIM_BEAM_WN)

representing different arrival directions of received signals. These signals are further multiplied(MM1-MMN) with a group of IF carriers.

The so generated signals ($C1_1$-$C1_N$) of all P modules TX_PROC are added (IF1-IFN), then D/A converted, are mixed with RF carriers and are then fed to the N inputs of said base station receiver, thereby simulating the signals that are typical for N-element array receiving antennas in a mobile radio environment.

Essential for the invention is the combination of the following features:

- Digital multiplication of N isofrequential replicas of phase modulated carriers with complex constants according to simulated arrival directions at an N-element array antenna;
- Application of the N generated simulation signals to N radiofrequency inputs of a receiver under test, thereby bypassing the antennas;

There is no hint in D1 which leads to these features.
The invention is therefore considered as both novel and inventive.

Re Item VII
Certain defects in the international application

1. In **claim 1**, the applicant has omitted the subject-matter of steps a) and b) defined in independent claim 1 as originaly filed.
   This omission introduces subject-matter which extends beyond the content of the application as filed, contrary to Article 19(2)/Article 34(2)(b) PCT.

2. In **claim 12**, the applicant has omitted the feature in line 29-34 ("Interface means...") of originally filed independent claim 13, page 25.
   Furthermore, the feature, that the "messages include the description of the modulation signals of useful and interferent transmission carriers" has been omitted.
   This omissions introduce subject-matter which extends beyond the content of the application as filed, contrary to Article 19(2)/Article 34(2)(b) PCT.

3. The present two-part form in the independent claims is misleading and superfluous and therefore inappropriate. Consequently, the independent

claims should have been drafted in one-part form.

4. The reference sign placed in parentheses (Rule 6.2(b) PCT) of the "means for adjusting the power level" in claim 12 is missing.

Re Item VIII
Certain observations on the international application

In general the inappropriate use of technical expressions and inconsistent wording used in the claims lead to severe clarity problems which render the subject-matter for which protection is sought unclear (Article 6 PCT). The applicant's attention is drawn to the fact that the claims are not understandable without the necessity to refer to the drawings or description.

In the following paragraph the main unclarities resulting from passages which are ambiguously formulated, misleading or inappropriate are addressed individually:

Claim 12, page 23:

The difference between a " radiofrequency receiver", a "receiver under test" and a "directional receiver" is not clear.

line 11: "...for generating serial messages directed to orthogonal modulation"

line 13: "..comprehensive of..."

line 14: it is not clear to what is referred by "which", and it is not clear whether the "test signal" or the "impairments" include co-channel interference.

lines 17-22: "self-generated" does not seem to be a well-defined technical term commonly used in the art.

It is not clear what the input and output of the NxP digital modulators are.

It is further not clear, what a "directional receiver" is.

It is further not clear, what the difference between "band carrier", "base band carrier" and a "phase modulated carrier" is. The expression "band carrier" does not seem to be a well-defined technical term commonly used in the art.

"being P chosen" has been understood as " P being chosen...". Further, it is not clear, which signals are "isofrequential", and how signals in "base band" can be isofrequential.

Stil further, the difference between "replicas", "digital replicas" and "base band replicas" (cf. line 24) is not clear.

lines 23-24: the formulation "...for every P groups of N replicas..." conveys the impression, that there are P times NxP (NxP^2 in total) first digital multipliers.

line 26-27 "being.." seems to be placed in a misleading part of the sentence , and the "successive products" are not defined.

lines 28-29: The wording of "...to an its own desired arrival direction to simulate" as such is not clear, and without reference to "received signals" it is not clear, what "arrival directions" are meant.

line 30: It is not clear, which power level is adjusted by "means for adjusting the power level".

lines 33-34: "conversion of the group at a respective intermediate frequency..."

Claim 12, page 24:

line 4: it is not clear, whether the "order" refers to N or P.

line 9: it is not clear what is mixed with what by the "mixers"

line 13: "and orderly sent"

Furthermore, the difference between a " radiofrequency receiver", a "receiver under test" and a "directional receiver" in claim 12 is not clear.

Claim 13, page 24:

line 23: "each (consisting?) of N replicas"

Claim 20, page 25: It is not clear, to which duration "said duration" refers to.

The same unclarities appear in the method claims 1-11, which comprise features corresponding to the apparatus claims 12-21.Furthermore, in claim 1, line 32, the expression "filtering they for..." is not clear.

"SIMULATION PROCESS OF RADIOFREQUENCY SCENARIO IN RADIO MOBILE ENVIRONMENT AND TESTING SYSTEM EMPLOYING SAID PROCESS"

Field of the Invention

The present invention relates to the field of test systems for telecommunication equipment and more in particular to a radiofrequency scenario simulation process in mobile radio environment for the testing of receivers of base transceiver stations with intelligent antennas, and testing system employing said process.

Before introducing the art known in the field of the invention, it is necessary to briefly describe the operation and problems related to the use of the so-called "intelligent" antennas; to justify, in the applicant's opinion, the lack of testing systems oriented to such a kind of antennas.

As it is already known, the use of intelligent antennas commences in the mobile radio environment to render the reutilization of the same carrier frequencies in cells of adjacent clusters less critical. This critical character is particularly evident in high traffic urban environment, where reutilization distances can suffer a considerable reduction due to the reduced dimensions of the cells, often of some hundreds of metres only. The use of traditional omnidirectional antennas, or of trisectorial ones, involves high interference problems in these particular environments by isofrequential signals coming from adjacent clusters. This is due to the scarce directivity of the antennas, which consequently involves the transmission of comparatively high power signals by the base transceiver stations (BTS). On the contrary, the intelligent array antenna, is a directive radiant system, able to concentrate the electromagnetic field in the original estimated direction of the signal transmitted by a generic mobile MS (in all the directions of the azimuth plane), separately for all the mobiles of a cell where the antenna is allocated. The antenna is therefore characterized by dynamic radiation diagrams (as many as are the time division carriers assigned to the BTS multiplied by the number of time slots) fit with main lobes of reduced angular opening that follow up the directions of the relevant mobiles, thus avoiding to vainly leak power out of these directions. Reciprocally in reception, this involves a reduction of the total level of isofrequential interferents and, consequently, of the reutilization distance of the same carriers, and therefore of the dimensions of clusters.

It is also known that the intelligent antennas are based on the use of electromagnetic field sensor arrays, each sensor being connected to its own transceiver, and the whole of transceivers to a process module able to duly process the signals received, or transmitted, by the single sensors. Usually, the receiver acts as "master", that is, it estimates on the azimuth plane the arrival directions of signals of the mobiles in transit in its cell and communicates this information to the transmitter that synthesises the angular openings of the antennas in the above mentioned angular directions, supplying the single sensors with replicas of a same signal, duly phase shifted among them.

While for the transmitter associated to an intelligent array antenna there is no particular realization problem, the same is not true for the implementation of the similar receiver, since the estimate of the arrival directions of useful signals is a complex operation from the computation point of view. It requires in fact an opportune processing of the module and phase information of more replicas of the radio signal received by the different sensors of the array. Said complexity derives from the fact to distinguish in the signal transduced from the array, the directions of the useful signals from those of relevant interferent signals, that is the isofrequential signals emitted by mobiles transiting in adjacent cluster cells, and the echoes due to the multiple reflections of the useful by obstacles spread over the territory, whose extent and time delay depend on the geographic environment of the cell (urban, suburban, rural environment). This information on the arrival directions is then used by the receiver to perform a spatial filtering of the N signals transduced by the array, in order to filter the useful from the different interferents.

<u>Background Art</u>

In the examples of base transceiver stations with intelligent antennas according to the known art, a similar discrimination of the useful from the interferents is only partially made. This does not happen for a newly conceived base transceiver station, implemented by the same applicant, whose main innovative aspects have been protected by the following relevant patent applications:

- EP 0 878 974under the title "Communication Method for cellular telephone systems ", filed on May 16, 1997;
- WO 99/33141 under the title "Discrimination process of a useful signal by a plurality of isofrequential interferent signals received by array antennas of base transceiver stations for cellular telecommunication and relevant method".

In particular, the last mentioned application solves the problem of discrimination of the useful signal from a plurality of isofrequential interferents through a spatial filtering method, or beamforming, made on signals transduced by the array, previously submitted to a processing determining the number and the arrival directions of the waves incising on the array, distinguishing the useful from the relevant interferents.

Therefore, it is evident that in testing systems of base transceiver stations equipped with intelligent antenna, of old conception, the problem to simulate a radiofrequency scenario reflecting as precisely as possible what actually occurs in the reality, is not particularly perceived. This is a consequence of the fact that the beamforming algorithms there used do not discriminate (or do it in a rough and predictable manner) the useful signals from the relevant interferent echoes. It is then possible, and in the practice it generally occurs in the context of the known art, to use the old test equipment for receiver apparatus of the base transceiver stations, with omnidirectional or trisectorial antennas, apart from the simulation of the arrival directions of useful and relevant interfering echoes. Consequently, the actual test of the behaviour of the receiver complete with intelligent array antenna requires opportune test transmitters located, ad hoc, on the territory.

US Patent No. 5,539,772 is an example of a test equipment designed for verifies the performance of a digital satellite receiver belonging to a mobile terminal unit. As known, a geostationary satellite retransmits towards the mobile a phone call received from a satellite ground station, in turn connected to a public telephone network. The relevant claim 1 of the citation discloses an Apparatus for verifying performance of a RF receiver, comprising:

- arbitrary waveform generator means for outputting an analog in-phase waveform and an analog quadrature waveform in accordance with sampled digital waveform data, said arbitrary waveform generator means including parallel first and second First-In-First-Out random access memories for storing the sampled digital waveform data;
- the sampled digital waveform data comprising an in-phase waveform file stored in said First-In-First-Out memory and a quadrature waveform file stored in said second First-In-First-Out memory
- each of the in-phase and quadrature waveform files including 60% root-cosine differential quadrature phase shift keyed data corresponding to successive frames of primary transmission channel data, co-channel interference data, adjacent

channel interference data, and data relating to at least one of a plurality of impairments;

- unity gain reconstruction filter means, connected to said arbitrary waveform generator means, for smoothing the analog in-phase and quadrature waveforms
- vector signal generator means, responsive to the filtered analog in-phase and quadrature waveforms, for outputting a modulated RF signal; and
- means for coupling an input of the RF receiver to the modulated RF signal output from said vector signal generator.

A further independent claim of the same cited prior art is directed to a method for testing the receiver. In accordance with the claimed method a digital frame including a portion dedicated to reproduce the signal transmitted, via satellite, to a mobile telephone unit is generated. Except for the framed digital signal, the claimed method has the substantial features of the claimed apparatus. In the supporting description all the means involved in claim 1 generates a narrow band test signal, which because a mobile telephone unit activates only a telephone call at a time, contrarily to the base station which activates a plurality of simultaneous calls. Accordingly, the signal generated by the test apparatus of the citation is unsuitable to test a base station, where a suitable test signal should be of the multicarrier type. In the particular case of GSM with beamforming, a minimal realistic test apparatus is charged to synthesize a useful signal freely displaceable inside a wide radiofrequency band, i.e. the 880-915 MHz for extended GSM, plus one or more co-channel interferent having a presettable direction out of 360°. A more versatile apparatus could generate several sets of similar signals at the various frequencies. No suggestion is given in the citation about the design of such a test apparatus.

Summary of the Invention

A general object of the present invention is to propose a simulation process of radiofrequency scenario for the testing of radio receivers with intelligent array antenna, able to identify the direction of a useful signal from those of isofrequential interferents, irrespective of the fact that a spatial filtering is then made.

Elective object of the present invention is that to overcome the drawbacks of testing systems for receivers of base transceiver stations of cellular telephone systems of old design, and to propose a radiofrequency scenario simulation process in mobile radio environment for the testing of radio receivers of base transceiver stations with intelligent antennas, of new generation, as much realistic as possible, for the whole

typology of signals which can incise on the antenna, that is: the useful signals emitted by several mobiles, the relevant echoes due to multiple reflections, the isofrequential interferents due to the reutilization of the carriers, the echoes of said interferents, the interferents from adjacent channel, the echoes of said interferents.

a) To attain these objects, scope of the present invention is a simulation process of radiofrequency scenario, in particular for the testing of receivers for N sensor intelligent array antennas, as described in claim 1.

Profitably, the subject process can be used for the simulation of a radiofrequency scenario of any cellular telephone system, characterized by the reutilization of carriers. The simulated scenario can be tailored in the way time by time considered more adequate to a particular testing requirement.

According to another aspect of the invention, the simulated scenario has dynamic characteristics, obtained varying at pre-set time intervals the setting of parameters relevant to characteristic magnitudes of useful and interferent carriers contained in said tables, which define the simulated scenario, such as for instance: level, delay, arrival direction, etc., the duration of said intervals being rather short to be comparable to the time slot employed by similar variations when occurring in a real scenario, but however sufficient to the reprogramming of the different phases of the simulated scenario.

Profitably, the simulation of the scenario includes the presence of noise, the doppler effect due to the speed of mobiles and the quick and sudden fadings of the electromagnetic field received, caused by destructive interference from multiple paths (fading of Rayleigh) or masking by obstacles of different nature encountered by the mobiles.

Since the intelligence of the receivers of a base station for mobile radio systems with intelligent antenna of new generation has the characteristics mentioned above, it results that the testing of these intelligent characteristics requires an adequate stimulation by the testing system, which shall be able to reproduce a radiofrequency scenario so richly diversified.

Therefore, further object of the invention is a testing system of receivers of a base station per mobile radio systems with intelligent array antenna, of new generation, employing the scenario simulation process scope of the present invention, as described in claim 12.

The great advantage that a similar system has, is to enable a complete and accurate testing of the receivers of the above mentioned base station, without the need

of preparing sample transmitters on the territory. The system is also characterized by an exceptional flexibility in preparing the scenario considered time by time more suitable to the verification of the receiver performance compared to a particular specification standard. In fact, it is sufficient that the testing operator fills in a limited number of tables describing the scenario to simulate, afterwards, simply clicking with the mouse the same become operative in real time.

Brief Description of Drawings

The invention, together with further objects and advantages thereof, may be understood making reference to the following detailed description, taken in conjunction with the accompanying drawings, in which:

- fig.1 shows a quite general block diagram of the testing system scope of the present invention, connected to a device to be tested (D.U.T.);
- fig.2 shows more in detail a SIM_RF block of fig.1 belonging to the above mentioned testing system;
- fig.3 shows the SIM_RF block of fig.2 with higher detail, up to the indication of the single circuit blocks;
- fig.4 gives a representation of the directions of plane waves incising on an array antenna, usually employed during the actual operation by the device to be tested (DUT) of fig.1;
- fig.5 shows the progressive phase shifting existing among the components of a plane wave front coming from a direction φ of fig.4, on the moment the same incises on the sensors of the array;
- fig.6 shows a picture on the complex I/Q plane of the rotating vectors that represent the components of the plane wave front of fig.5; and
- fig.7 shows the tables previously stored in the permanent storage of the processor of fig.1, available to the testing operator for the setting of the parameters distinguishing a scenario to be simulated.

Detailed Description

Making reference to fig.1, it can be noticed a testing system of a device DUT (Device Under Test) consisting of a simulation equipment SIM_RF connected to a control processor CNTR_PC through a serial bus ET_LAN of a local network, for instance of the Ethernet type, to which also the DUT device is connected.

The SIM_RF block has N radiofrequency outputs out1, out,2, ..., outN connected, through N coaxial cables, to a same number of inputs in1, in2, ..., inN of the DUT block.

Relevant radiofrequency signals RF1, RF2, ..., RFN coming out from the SIM_RF block run along said cables, and enter the DUT block. Blocks SIM_RF and DUT, as well as the personal computer CNTR_PC, are connected to the serial bus ET_LAN. More in particular, the personal computer CNTR_PC is connected to the ET_LAN bus through its own serial bus SER_PC, the DUT block through a serial bus SER_DUT, and block SIM_RF through M serial buses SER_PR1, SER_PR2, ..., SER_PRM and a M+1-th serial bus SER_LO.

In operation, the SIM_RF block is a simulation equipment governed by the personal computer CNTR_PC, and the DUT block is a receiver of a base transceiver station (BTS) for cellular telephone system of the FDMA/TDMA type, for instance GSM 900 MHz, or DCS 1800 MHz. The whole of the RF1, ..., RFN signals conforms to the selected standard that defines the radio interface. Even if not shown in the figure, the above mentioned blocks include one or more interface devices towards the local network ET_LAN.

Observing the testing configuration of the figure (test bed), we can perceive the great advantage offered by the connection in local network both of the testing system CNTR_PC, SIM_RF and of the device to test DUT. In fact, this last could send the results of the different tests directly to the computer CNTR_PC, in a completely asynchronous mode versus the flow of testing data. The control processor will avail of evaluation procedures and print of the results, and in the case of variation of input stimulations. In this way the testing will result completely automated.

Making reference to fig.2, we notice that the simulation equipment SIM_RF includes M processor modules TX_PROC1, TX_PROC2, ..., TX_PROCM; N broad band radiofrequency transmitters WB_TX1, WB_TX2, ..., WB_TXN; and a LO_CORP block generating N identical signals of local oscillator OL, reaching the transmitters WB_TX1, ..., WB_TXN.

Each TX_PROC block has N outputs for a same number of digital sequential words Cx_y reaching the relevant N parallel buses BS1, BS2, ..., BSN, where the value of index x indicates the origin from a relevant processor module m-th, while the value of index y indicates the n-th bus reached by the signal Cx_y. I bus BS1, BS2, ..., BSN are connected to an input of relevant broad band transmitters WB_TX1, WB_TX2, ..., WB_TXN identified by the same ordinal number.

In the operation, the architecture of the SIM_RF equipment shows a modularity per time division radio carrier, with a maximum of M carriers generated by M modules TX_PROC, and per antenna element, with a maximum of N elements (virtual), supplied

by a same number of signals coming out from the WB_TX transmitters. Each module TX_PROC generates also the N-1 replicas of its own carrier, duly phase shifted, necessary to control the modularity per antenna element (virtual).

The processor modules TX_PROC perform the following operations, in a completely digital manner:

- acquisition of control signals by the processor CNTR_PC, as serial messages withdrawn from the bus ET_LAN;
- generation of P numeric isofrequential carriers and GMSK modulation of the same using an identical modulating signal, obtaining components in phase I and in quadrature Q of each carrier;
- multiplication of the samples of said components I and Q by relevant complex constants coming from CNTR_PC, originating "weighed" components in phase and module in order to realize beamforming, as we shall see below;
- vectorial sum of I and Q "weighed" components of each carrier, obtaining in change digital modulated carriers GMSK;
- level control of the above mentioned modulated carriers in steps of programmable amplitude;
- control of the ramp-up and ramp-down time of the envelope of the modulated signal, at the beginning and at the end of each burst, respectively (ramp-up and ramp-down functions);
- numeric conversion at intermediate frequency of each modulated carrier, obtaining said digital words Cx_y;
- construction of N transmission digital signals of the multicarrier type at intermediate frequency, identified IF1, IF2, ..., IFN, respectively, coinciding with the buses BS1, BS2, ..., BSN, through sum of each m-th word Cx_y identified by the same index y.

Signals IF1, IF2, ..., IFN reaching the N broad band transmitters WB_TX1, WB_TX2, ..., WB_TXN, are converted to analogue by the same, typically compensating the distortion of the senx/x type, broad band filtered, and then converted at radiofrequency in test signals RF1, RF2, ..., RFN placed in a selected transmission sub-band. The N signals RF1, RF2, ..., RFN, thanks to the beamforming, are suitable to simulate up to M different arrival directions from a unique spatial point. The same directions are in fact recognized by the receiver DUT per intelligent antenna of a BTS in testing phase, and therefore without antenna, on the basis of the reciprocal phase shifting existing between the N carriers of each of the M groups of N isofrequential

carriers forming the N broad band signals RF1, RF2, ..., RFN, globally conveyed in the DUT block by a same number of coaxial cables.

Fig.3 highlights with higher circuit detail what already said in the comment of fig.2; in particular it is supplied the architecture of processor modules TX_PROC and of transmitters WB_TX.

Making reference to fig. 3, in which the same elements of the previous figures are indicated with the same symbols, we notice the processor modules TX_PROC1, TX_PROC2, ..., TX_PROCM of which, only for module TX_PROC1, the internal architecture is highlighted, being the architecture of the remaining modules identical to the highlighted one. The TX_PROC1 module includes N modulators GMSK1, GMSK2, ..., GMSKN and a INTF_PC block connected, through the serial bus SER_PR1, to the serial bus ET_LAN of the local network to which all the remaining blocks TX_PROC are abutted, the LO_CORP block, as well as the personal computer CNTR_PC and the DUT block highlighted in the testing configuration (test bed) of fig.1. At output of the INTF_PC block, digital signals are present, indicated as follows:

- SIM_D, BT_SIM, and SIM_DEL directed towards all the GMSK modulators;
- N complex data SIM_BEAM_W1, SIM_BEAM_W2, ..., SIM_BEAM_WN addressed towards an input of relevant first complex digital multipliers M1, M2, ..., MN, the other input of which is reached by the components I and Q coming out from relevant GMSK modulators; and finally
- N identical digital carriers SIM_NCO addressed towards an input of relevant second digital multipliers MM1, MM2, ..., MMN, the other input of which is reached by the signals coming out from relevant first multipliers M1, M2, ..., MN (through the adders of the "weighed" I and Q components, omitted for briefness sake in the figure).

One clock input of GMSK modulators is reached also by a signal CK, used for the generation of relevant and identical digital carriers in base band.

At the output of the second multipliers MM1, MM2, ..., MMN the N signals $C1_1$, $C1_2$, ..., $C1_N$ of fig.2 are present; these last reach a first input of relevant N digital adders 1, 2, ..., N, having two inputs, also included in the TX_PROC1 block. The second input of said adders is reached by relevant sum signals of corresponding signals Cx_y generated by the remaining modules TX_PROC of the block SIM_RF. As it can be noticed in the figure, TX_PROC blocks are placed in cascade as for the adders 1 ... N, that is the output of a generic adder of a block reaches an input of the corresponding adder of the block placed downstream. Consequently, adders 1, 2, ..., N of the TX_PROC1 block, placed downstream the whole chain of blocks TX_PROC,

obtain at output the digital signals at intermediate frequency IF1, IF2, ..., IFN, as cumulative sum of relevant signals Cx, corresponding to those indicated on buses BS1, BS2, ..., BSN of fig.2. It results that the implementation of these last is actually obtained through the M groups of adders 1, 2, ..., N placed in cascade.

The N digital signals at intermediate frequency IF1, IF2, ..., IFN reach a same number of digital/analogue converters included in the relevant blocks WB_TX1, WB_TX2, ..., WB_TXN. Converted signals are duly broad band filtered, amplified, and sent to a first input of relevant mixers MX1, MX2, ..., MXN, reached also by the N identical signals of local oscillator OL coming from LO_CORP, obtaining at output N radiofrequency signals. These last are duly filtered and sent to relevant power amplifiers PA1, PA2, ..., PAN, obtaining the N signals RF1, RF2, ..., RFN present at the outputs out1, out2, ..., outN of SIM_RF.

All what said up to now concerning the operation of the SIM_RF equipment of figures 2 and 3 relates to what happens in a single time slot. This time (577 μs) is too short to complete the dialogue between CNTR_PC and SIM_RF and the required programming of modulators GMSK by the INTF_ PC block; consequently the settings of the SIM_RF equipment, for all the time slot of the present frame possibly involved, shall be made during a frame time (4,61 ms) and shall become operative during the subsequent GSM frame.

Continuing the description of the operation of the simulation equipment SIM_RF, it is impossible to leave out of consideration the dialogue between this last and the control personal computer CNTR_PC. Before describing the methods of such a dialogue it is useful to give some theoretical clarifications on the beamforming, used in the present invention to simulate the arrival direction of useful and interferents.

Making reference to fig.4, we notice an array antenna, seen from the top, consisting of N sensors a1, a2, a3, ..., aN aligned along a straight line and separated one from the other of a distance $d = \lambda/2$, at centreband frequency of the band assigned by the particular transmission standard valid for the type of BTS to be tested. The antenna has a plane form, whose trace on the figure plane corresponds to the sensors junction line. The antenna plane is stricken by two plane waves p1 and p2 coming from two different directions, indicated with two straight lines, perpendicular to the relevant wave fronts and forming two relevant arrival angles φ and θ with the trace of the antenna plane.

Making reference to fig.5, we notice the wave front p1 on the moment it strikes the sensor a1 placed at one end of the array. From the figure it is clear that the subsequent sensors shall be stricken with ever increasing delays, consequently the modulated carrier corresponding to the plane wave p1 shall be seen at the input of the different sensors of the array like N identical modulated carriers s1(t), s2(t), ..., sN(t), phase shifted among them by ever increasing angles. All these phase shiftings are therefore in biunivocal relation with the arrival direction of p1, so that to estimate the unknown arrival direction of a generic carrier coming from a mobile, it is sufficient to measure the reciprocal phase shiftings among the signals received from single sensors, taking an ending one to determine an absolute phase reference. This is just what the block DUT performs in its actual operation. Concerning the simulation equipment SIM_RF, the dual reasoning applies, that is, starting from a direction to simulate of a test carrier, it is necessary to calculate some complex constants (beamforming coefficients) which, multiplied by N identical modulated carriers p1 give the reciprocal phase shiftings identical to those of the wave front of fig.5. It is then clear that sending this set of carriers directly downstream the array, excluding this last, we obtain the same effect as that obtained sending a carrier from a direction φ with inserted antenna. The reasoning made for the carrier p1, whose arrival direction has to be simulated, applies to any other carrier, both useful or interferent, whose directions must be simulated them too. It is this possible to test from a unique spatial point, the laboratory one, through a simulated scenario, the characteristics of the receiver defining the intelligent behaviour of the same.

Referring to figures 5 and 6, it is now described the calculation of beamforming coefficients enabling to obtain the set of phase shifted carriers as desired. To this purpose, it is used in fig.6 a vectorial representation on plane I, Q of the modulated carriers s1(t), s2(t), ..., sN(t) of fig.5 present at the input of the single sensors a1, a2, a3, ..., aN, indicating the corresponding rotating vectors con $\mathbf{S}_1$, $\mathbf{S}_2$, $\mathbf{S}_3$, ..., $\mathbf{S}_N$. The phase absolute reference is selected arbitrarily assuming equal to zero the phase of vector $\mathbf{S}_1$. Indicating the vectors in exponential form with module A, and letting $\Psi = \pi \cos\varphi$, the following representation applies:

$$\mathbf{S}_1 = Ae^{j0}$$

$$\mathbf{S}_2 = Ae^{j\frac{2\pi}{\lambda}d\cos\varphi} = Ae^{j\pi\cos\varphi} = Ae^{j\Psi}$$

$$\mathbf{S}_3 = Ae^{j\frac{2\pi}{\lambda}2d\cos\varphi} = Ae^{j2\pi\cos\varphi} = Ae^{j2\Psi}$$

....

$$S_N = Ae^{j\frac{2\pi}{\lambda}(N-1)d\cos\varphi} = Ae^{j(N-1)\pi\cos\varphi} = Ae^{j(N-1)\Psi}$$

The calculation of the Cartesian components of each vector is now immediate, according to the known trigonometric relations:

$$Q_1 = A$$
$$I_1 = 0$$

$$Q_2 = A\cos(\Psi) = A\cos(\pi\cos\varphi)$$
$$I_2 = A\sin(\Psi) = A\sin(\pi\cos\varphi)$$

$$Q_3 = A\cos(2\Psi) = A\cos(2\pi\cos\varphi)$$
$$I_3 = A\sin(2\Psi) = A\sin(2\pi\cos\varphi)$$

....

$$Q_N = A\cos((N-1)\Psi) = A\cos((N-1)\pi\cos\varphi)$$
$$I_N = A\sin((N-1)\Psi) = A\sin((N-1)\pi\cos\varphi)$$

The N pairs of values I and Q so obtained correspond to beamforming coefficients SIM_BEAM_W1, SIM_BEAM_W2, ..., SIM_BEAM_WN of fig.3. In the example considered, the mathematical process described above must be repeated for the calculation of beamforming coefficients of the carrier p2; in general, M procedure for each one of the M modulated carriers, generated by the SIM_RF equipment have to be made.

It is now described the dialogue method between the personal computer CNTR_PC and the simulation equipment SIM_RF, in order to better highlight the functions of the INTF_PC block of fig.3, missing in the mentioned known art. The above mentioned dialogue occurs through sending of messages from CNTR_PC directly towards the TX_PROC units; each message is transmitted in series with a label specifying the address of the TX_PROC addressee unit and the length of the associated message, immediately followed by the message content, that is the true data.

Making reference to fig. 7, messages are automatically prepared by the processor CNTR_PC, after the testing operator has filled in a limited number of predetermined tables TAB.1, TAB.2, ..., TAB.K, which summarize the general data describing the scenario to simulate. The selection of data to enter can determine the opening of submenus containing the parameters to select for the option specified. The

tabular display of SIM_RF setting data is made through windows selectable on the screen and connected among them, meaning that the modification of one or more data will affect in real time all the windows involved in said data. Clicking with the mouse, the operator opens a list of possible selectable values, for each case of the table. The operator can retrieve the tables at any moment during the testing and the possible updatings are operational in real time.

For a better comprehension of the fields given in tables of fig.7, of those that shall be included in subsequent subtables of the relevant submenus, and of those of additional tables which will clarify the content of the messages correspondingly generated, it is helpful to give just from now some brief preliminary notions on the fundamental aspects that define the radio Um interface of the system GSM, 900 MHz, to which the testing system and the device to be tested of the example shown in fig.1, make explicit reference. From these notions some operation specifications for the testing system of fig.1 will derive. As it results from the recommendations on this purpose:

- each BTS employs one or more radio carriers, each one allocated in the 900 MHz band (TX BTS : 925-960 MHz; TX MS : 880-915 MHz);
- a carrier BCCH (broadcast carrier) for the transmission, is associated to each cell, diffused to all the mobiles, of the cell characteristic information;
- each radio carrier is time divided in time slots of about 577 μs each, the transmission takes place in digital way with bit duration of about 3.6 μs;
- each time slot contains a Normal Burst of 148 bit, or an Access Burst of 88 bit;
- each Normal Burst contains a 26 bit synchronization sequence (Training sequence or middambolo), temporally positioned at the burst centre;
- the repeatitivity of the time slot occurs at frame interval of about 4.61 ms, for 8 time slot frames (TS0...TS7);
- 26 sequential frames are organized in a 120 ms multiframe; 51 sequential multiframes are organized in a 6,12 second superframe; 2048 sequential superframes are organized within an iperframe of approximately three hours and a half; such a subdivision is useful to synchronise events requiring long real times to be acquired and processed;
- the power emitted by the BTS on each time slot of each radio carrier has a level (Emission Level) depending on the distance separating BTS from MS (said distance is

evaluated on the basis of the TIMING ADVANCE parameter), and level and quality of the signal received.

From the above mentioned specifications it can be noticed that up to now, recommendations concerning the behaviour of the intelligent antenna do not exist.

The BTS controls the radio interface monitoring the following parameters (updated every 480 ms):

- distance of MS from BTS, proportional to the radio signal propagation time (parameter : TIMING ADVANCE);
- level of the signal received, depending on the attenuation of radio length separating MS from BTS, within the coverage along a specified direction (parameter: RX_LEV);
- useful/interferent ratio C/I, depending on the above mentioned considerations and essentially deriving from the concept of radio resources reutilization (RX_QUAL parameter).

Based on the general notions mentioned above, some operation specifications result for the testing system of fig.1 that, as it is remembered, consists of the simulation equipment SIM_RF connected to its own control processor CNTR_PC through a serial bus ET_LAN of a local network . The above mentioned specifications are given below:

standard of the radio interface	EGSM900
subdivision in 10 MHz sub-bands TX (because a wide band digital transmitter able to cover the whole band cannot be realized up to now)	875-885 MHz 885-895 MHz 895-905 MHz 905-915 MHz
Power rated level TX for carrier	-13 dBm at the output of each WB_TX
digital control TX power level (for channel)	15 steps, 1 dB each
Number of antenna elements TX	N = 8
Maximum number of RF carriers	M = 16
No. of time slots actually assigned	Set possibility for each carrier
simulation of movement for each RF carrier	Speed setting possible (3 ÷ 250 km/h)
relative delays between RF carriers	programmable with 1 bit GSM resolution (156 bit max)
relative delays between echoes of the same carrier	programmable with 50 ns resolution (3.6 μs max)

simulation of angular direction (for each RF carrier)	programmable on 360° with 1° resolution

Going back now to the general tables of fig.7, we can notice that a given number K is foreseen (only two of them are described in detail) each one referred to a subsequent GSM frame having 4.61 ms duration. This strategy enables to gradually vary the parameters of the simulated scenario, going close to what occurs in the dynamics of a real scenario. In fact, it is known that the algorithms used by a BTS to acquire the main merit parameters of the receiver require times longer than that of a single frame. Furthermore, in the case of receiver for intelligent antenna, like that of block DUT of fig.1, the same works with adaptive algorithms performing their function at best on several subsequent frames. La sequence of K tables is cyclically repeated to enable a continuous operation of the testing system. The cyclic repetition of tests enables the results of the measures to reach a permanent steady condition after each manual updating of one or more parameters of the scenario, and demonstrates to be useful for a statistical evaluation of results. The transformation methods of the information included in tables of fig.7 in messages for the SIM_RF equipment shall be described hereafter.

The items indicated in the different cases of the general tables of fig.7 are self-explanatory and do not require additional comments. Concerning the connection of the general tables to submenus, the choice "FREQUENCY HOPPING: YES" determines the opening of a submenu with the following parameters to set:

PARAMETER	IDENTIFICATION	RANGE
n° channels RF available	N	1...50
n° selected hopping sequence	HSN	0...63
offset of the allocation index of MS	MAIO	0...N-1

The option "FADING: NO" does not determine opening of any submenu.

The option "FADING: YES" determines the opening of a submenu for the selection of one of the following known propagation models:

PROPAGATION MODEL	IDENTIFICATION
rural area	RAx (6 taps)
hilly terrain	HTx (12 taps)
reduced hilly terrain	HTx (6 taps)

urban area	TUx (12 taps)
reduced urban area	TUx (6 taps)
equalization test	EQx (6 taps)
arbitrary	CUSTOM

The selection of any propagation model (excluding CUSTOM) imposes the values of " RF level ", "delay" and "Doppler spectrum type" of the table of fig.7, which determined this choice. Access to the columns of the above mentioned table is therefore inhibited to the operator, and the values automatically included in these columns are those defined by specifications GSM 05.05 Annex C (Propagation conditions). Furthermore, rural area models, reduced hilly terrain, reduced urban area, equalization test automatically engage 6 carriers of SIM_RF; the hilly terrain, urban area models automatically engage 12 carriers of SIM_RF. The selection of the discretionary model (CUSTOM) determines the enabling of the columns "delay" and "Doppler spectrum type" and the engagement of one sole RF carrier, since the selection of the number and characteristics of possible echoes and of the possible (taps) of the model itself is up to the operator.

Once the tables of fig.7 are filled in with the data for the simulation, guided in this by the relevant submenus, the processor CNTR_PC generates the messages instructing the processor modules TX_PROC1, TX_PROC2, ..., TX_PROCM and the block LO_CORP.

The following table lists the identification names of messages and the relevant addressee units:

TYPE OF MESSAGE	Bit No.	PC→ TX_PROC	PC→ LO_CORP
SIM_NCO (1...16)	8	x	
SIM_D (1...16)	116	x	
SIM_BEAM_Wn (1...16)	256	x	
SIM_DEL (1...16)	16	x	
BT_SIM	8	x	
P_SYNT_SIM	8		x
TSN	8	x	

All the messages having suffix (1...16) are intended as separate messages sent to the TX_PROCm module relevant to the carrier m-th (m 1 to 16). Concerning the SIM_BEAM_Wn messages, the suffix n varies from 1 to N = 8 coinciding with a generic value m to indicate N separate messages sent to the same module TX_PROCm.

The following table gives the meaning of the messages listed in the previous table:

NAME	Bit No.	MEANING
SIM_NCO	16	Programming of the RF channel transmitted in uplink
SIM_D	116	data to be transmitted in uplink (modulating signal)
SIM_BEAM_Wn	256	Module and phase of beamforming coefficients
SIM_DEL	16	delay of the simulated carrier in uplink
BT_SIM	8	training sequence code, TSC (3 bit) + selection between NORMAL or ACCESS burst (1 bit)
P_SYNT_SIM	256	programming of LO_CORP for the selection of the carrier in the assigned time slot
TSN	8	number of the time slot of the GSM frame (TSN=0...7)

The necessary procedures to process data supplied by the user and to obtain the information message in the serial format accepted by the network ET_LAN and by interface blocks INTF_PC of the simulation equipment SIM_RF are developed on CNTR_PC. Following is the list of the above mentioned procedures, specifying the procedure input information (inputs) and the information supplied by the procedure itself (outputs). The inputs are the parameters selected by the user and entered through menu and submenus. The outputs contain the messages transferred by CNTR_PC, via bus ET_LAN, to modules TX_PROC and LO_CORP.

The procedures performed by CNTR_PC for the generation of the above mentioned messages are the following:

- **frequency hopping algorithm** (see spec. GSM 05.03)
  inputs : N,HSN,MAIO $\Rightarrow$ outputs : RF channel number;
- **beamforming algorithm** (see the previous representation of figures 4, 5 and 6)

inputs : arrival angle ⇒ outputs : beamforming coefficients;

- **RF scenario simulation** (see spec. GSM 05.05 Annex C, propagation condition) inputs : standard propagation model, MS speed ⇒ outputs : sequence of amplitude multiplication coefficients (one per frame); relative delays between echoes of the same carrier.

Making reference to fig.3, we can notice that a great part of the content of messages transferred by CNTR_PC, via ET_LAN, to the interface circuit INTF_PC, are in their turn transferred to using devices. This occurs for the contents of the messages SIM_D, TSN and SIM_DEL, transferred to modulators GMSK; for the contents of the messages SIM_BEAM_Wn, transferred to first multipliers M1, M2, ..., MN; and for the content of the message SIM_NCO, transferred to the second multipliers MM1, MM2, ..., MMN.

The contents of all the messages are updated by CNTR_PC at each 4.61 ms GSM frame, and sent according to the same intervals to the concerned units placed in local network, even if the content of a message is unchanged compared to that of the preceding frame. Consequently the concerned modules TX_PROC and LO_CORP, can process in a frame time the updated contents of the relevant messages, in order to be able to change in real time the simulated magnitudes relevant to the modulated carriers sent to the DUT block of fig.1 in the subsequent frame.

The updating of the message content made by CNTR_PC of fig.1 at each frame, in absence of modifications introduced by the testing operator in the contents of the sequence of K tables of fig.7, and of subtables associated to the same, shall be that imposed by said sequence. On the contrary, in presence of modifications, it will reflect that of the updated sequence, starting from the point in the recurrent cycle in which the same is rendered operative. For a better understanding of the updating dynamics of messages generated by CNTR_PC, it is appropriate to underline that the compilation of the sequence of K tables of fig.7 is completely made out of line, both concerning the first drawing up and the successive modifications. Afterwards, the testing operator confirms the new version that becomes operative in real time, meaning that from that moment on, the messages sent to the network shall be generated starting from the tables of the last version, without stopping for this reason the flow of sequential messages. We can therefore conclude that while the compilation phase is completely independent from the flow of messages, the deriving updating in the content of

messages, coinciding with the sending of new messages to the network, occurs in synchronous way compared to the frame interval.

From the analysis of information included in the tables of fig.7 and relevant menus, and from the typology of the deriving messages, we can deduce that availing, in whole, or in part, of the M = 16 groups of carriers relevant to a same time slot, each group including N = 8 replicas can be arbitrarily simulated:

- one or more useful signals;
- one or more isofrequential interferent signals (that in a real scenario are due to reutilization of the carriers in adjacent clusters) coming from directions separate from that of the relevant useful;
- one or more echoes of a useful, and/or interferent signal, (that in a real scenario are generated by multiple paths) coming from directions different from that of the useful and/or interferent;
- one or more interferents from adjacent channel, and relevant echoes; and also
- the fading effect on each one of the above mentioned signals, in non-correlated mode compared to the other signals, through multiplication of beamforming coefficients by a duly filtered pseudo-noise sequence. The operations concerning this point are directly performed by CNTR_PC through pre-processing.

The testing system of fig.1 is very flexible as for the panorama of possible scenarios to simulate, and easy to handle for the testing operator, whose task is limited to the entering of data in the general tables of fig.7. These advantages derive from the essentially digital architecture of the simulation equipment SIM_RF, which can construct N broad band digital signals at intermediate frequency IF1, ..., IFN, of the multicarrier type. Each carrier included in the broad band signals IF1, ..., IFN is characterized by a relevant content of the SIM_NCO message, which established the relevant intermediate frequency; therefore the simulation of several isofrequential interferents engages several modules TX_PROC to which SIM_NCO messages having identical content are sent.

Generalizations

The simulation system of the example lends itself to some generalizations that configure the invention applicable to other mobile radio systems with system setting different from the FDMA/TDMA one. For instance, as far as the invention is concerned, the TDMA aspect is not strictly necessary and, strictly speaking, also the FDMA aspect can be not considered, since for the simulation of a minimum, but realistic scenario,

one sole carrier is sufficient with its isofrequential interferents. As for the invention, if we want to leave out of consideration the FDMA/TDMA architecture of the embodiment, we must be considered the dynamic characteristic of the simulated scenario which up to now was given by the updating of the significant parameters of the same at 4.61 ms interval of the GSM frame. This time slot is a good compromise between the need to avail of a processing time sufficient to the generation of configuration messages of the scenario, to their transfer on local network, and to the programming of the addressee units of the content of the same, and that to be able to simulate a realistic time slot in which the variations indicated by the succession of parameters, correspond to a same variation of the same magnitudes, but referred to phenomena which in the real context comprise the involved carriers.

From the above we can conclude that it is possible to employ the present invention to simulate the radiofrequency scenario in the testing of a base transceiver station of a cellular telephone system of the analogue type with FDMA philosophy, for instance TACS. In this case, whenever the processing times enable it, it is possible to update the scenario parameters with interval lower than 4.61 ms of the example, reaching a finer accuracy in the dynamic simulation.

From what said up to now we can conclude that, without departing from the field of the invention, the same can have further applications, in addition to those foreseen for cellular telephone systems. For instance, it is possible to use the invention in all the cases where it is necessary to test receivers for intelligent array antennas employing beamforming algorithms, but leaving out of consideration the basic philosophy of all the mobile radio telephone systems, and therefore the fact that all the interferents are caused by the reutilization of the same carriers in a territory subdivided in cells of adjacent clusters.

Possible applications of the invention in this way could be forecast in the satellite sector. Other possible applications of the invention in sectors different from the mobile radio telecommunication one, could be predicted in the radar sector.

AMENDED CLAIMS

1. Simulation process of a radiofrequency scenario starting from generation of serial messages including useful information (SIM_D, BT_SIM, SIM_DEL) for obtaining a phase-modulated radiofrequency test signal comprehensive of the most relevant channel impairments, including co-channel interference, which is sent to the input of a receiver under test (DUT) whose output is monitored, **characterized in that** includes the following further phases piloted by the message contents:

- execution of N×P digital modulation of a base band carrier, for obtaining P groups (carrier 1, ..., carrier M) of N base band isofrequential digital replicas of said phase-modulated carrier, being P chosen from 1 to the maximum number M of modulated carriers fitting the assigned band of the receiver under test (DUT), and N being the number of independent inputs of said receiver;
- digital multiplication, for every P groups of N replicas, of each base band replica by a respective complex constant (SIM_BEAM_W1, SIM_BEAM_W2, ..., SIM_BEAM_WN) assigned to the group, being the numerical order of the replicas and the phases of the multiplicative constants both increasing gradually in the successive products for beamforming each of the P group of N replicas according to an its own desired arrival direction to simulate;
- adjustment of the power level of each P group of N replicas;
- digital multiplication of each beamformed group of N replicas by a relevant digital intermediate frequency carrier (SIM_NCO) which carries out frequency conversion of the group at a respective intermediate frequency, so establishing for each intermediate frequency converted beamformed group ($C1_1$, $C1_2$, ..., $C1_N$; .... ; CM_1, CM_2, ..., CM_N) the relative position inside the broad band of the receiver under test;
- summation of all the P intermediate frequency converted replicas having the same order in each beamformed group, for obtaining N broad band intermediate frequency replicas (IF1, IF2, ..., IFN);
- analogue conversion of the N broad band intermediate frequency replicas (IF1, IF2, ..., IFN) and filtering broad band the analogue replicas for reconstruction;
- radiofrequency conversion of the reconstructed analogue replicas, amplifying and filtering they for obtaining N broad band radiofrequency replicas (RF1, RF2, ..., RFN) constituting a single test signal suitable for testing the operation of a

directional receiver, preferably one included in a base station of a radiomobile system designed for cooperating with a N-elements directive array;

- application of the N broad band radiofrequency replicas (RF1, RF2, ..., RFN) directly to N radiofrequency inputs (in1, in2, ..., inN) of the receiver under test (DUT), bypassing the antenna.

2. Simulation process of radiofrequency scenario according to claim 1, characterized in that the content of said serial messages (SIM_D, SIM_PN, SIM_DEL, SIM_BEAM_W1, ..., SIM_BEAM_WN, SIM_NCO, OL) is read from general tables (TAB.1, TAB.2, ..., TABK) of parameters and options defining a scenario concerning at least one useful transmission signal and one or more isofrequential interferent signals, having simulated arrival directions generally different from those of said relevant useful signals.

3. Simulation process according to claim 2, characterized in that said general tables (TAB.1, TAB.2, ..., TABK) constitute a sequence of K tables cyclically read.

4. Simulation process according to claim 3, characterized in that its operative phases form a sequence repeated at time intervals of the same duration, using time by time said messages obtained converting a new general table of said cyclic sequence, thus giving dynamic and recurrent characteristics to said simulated scenario.

5. Simulation process according to claim 4, characterized in that said equal duration of the time intervals is such that the variation speed of the contents of said messages is similar to the one that can be detected in the corresponding said parameters of a real scenario.

6. Simulation process according to claim 5, characterized in that said duration is equal to, or lower than 4.61 ms.

7. Simulation process according to any claim 4 through 6, characterized in that said general tables (TAB.1, TAB.2, ..., TABK) are updated during the testing time, and corresponding updated messages are generated in synchronous mode compared to said sequential time intervals.

8. Simulation process according to claim 4, characterized in that it includes an additional acquisition phase of the results of said testing, in asynchronous mode compared to said sequential time intervals.

9. Simulation process according to any claim from 2 to 8 characterized in that the selection of some of said options of said general tables (TAB.1, TAB.2, ..., TABK) involves the compilation of relevant sub-tables containing additional parameters to select for the specified option.

10. Simulation process according to any claim from 4 to 9, characterized in that said carriers are time division multiplexed, and each of said sequential time intervals of the same duration corresponds to a frame time.

11. Simulation process according to any claim from 2 to 10, characterized in that said general tables (TAB.1, TAB.2, ..., TABK) include also parameters that take into account the presence of noise, the doppler effect due to the speed of the mobiles, and the quick and sudden fading of the electromagnetic field received, caused by multiple paths destructive interference or by masking by obstacles encountered by mobiles in movement.

12. Testing system of a radiofrequency receiver, including a control processor (CNTR_PC) for generating serial messages directed to orthogonal modulation and frequency conversion devices controlled by the content of said messages for generating a phase-modulated radiofrequency test signal comprehensive of the most relevant channel impairments, including co-channel interference which is sent to the input of a receiver under test (DUT) whose output is monitored, **characterized in that** it further includes:

- N×P digital modulators (GMSK1, GMSK2, ..., GMSKN) of a self-generated base band carrier, for obtaining P groups (carrier 1, ..., carrier M) of N base band isofrequential digital replicas of said phase-modulated carrier, being P chosen from 1 to the maximum number M of modulated carriers fitting the assigned band of the receiver under test (DUT), and N being the number of independent inputs of said receiver;
- N×P first digital multipliers (M1, M2, ..., MN; ...) arranged for multiplying, for every P groups of N replicas, each base band replica by a respective complex constant (SIM_BEAM_W1, SIM_BEAM_W2, ..., SIM_BEAM_WN) assigned to the group, being the numerical order of the replicas and the phases of the multiplicative constants both increasing gradually in the successive products for beamforming each of the P group of N replicas according to an its own desired arrival direction to simulate;
- means for adjusting the power level of each P group of N replicas;
- N×P second digital multipliers (MM1, MM2, ..., MMN; ....) for multiplying each beamformed group of N replicas by a relevant digital intermediate frequency carrier (SIM_NCO, ...) which carries out frequency conversion of the group at a respective intermediate frequency, so establishing for each intermediate frequency converted

beamformed group ($C1_1$, $C1_2$, ..., $C1_N$; .... ; CM_1, CM_2, ..., CM_N) the relative position inside the broad band of the receiver under test;

- N digital adding means (1, 2, ..., N) for summing up all the P intermediate frequency converted replicas having the same order in each beamformed group, for obtaining N broad band intermediate frequency replicas (IF1, IF2, ..., IFN);
- N digital/analogue conversion means (D/A) of said N broad band intermediate frequency replicas (IF1, IF2, ..., IFN) followed by broad band filtering means for reconstructing the analogue replicas;
- N radiofrequency mixers (MX1, MX2, ..., MXN) of said N broad band reconstructed analogue replicas (IF1, IF2, ..., IFN) for obtaining N broad band radiofrequency replicas (RF1, RF2, ..., RFN);
- N radiofrequency amplifiers (PA1, PA2, ..., PAN) for amplifying said radiofrequency replicas (RF1, RF2, ..., RFN) and orderly sent them to N radiofrequency outputs (out1, out,2, ..., outN) of the testing system, where the radiofrequency replicas constitute a single test signal suitable for testing the operation of a directional receiver, preferably one included in a base station of a radiomobile system designed for cooperating with a N-elements directive array;
- a whole of N coaxial cables, or equivalent means, connecting said N radiofrequency outputs to a same number of inputs (in1, in2, ..., inN) of a said receiver (DUT), without antenna.

13. Testing system according to claim 12, characterized in that the intermediate frequency converted beamformed groups ($C1_1$, $C1_2$, ..., $C1_N$; .... ; CM_1, CM_2, ..., CM_N), each of N replicas, are generated by means of P identical digital modules (TX_PROC1, ..., TX_PROCM), each including a dedicated processor interface (INTF_PC) communicating with N digital modulators (GMSK1, GMSK2, ..., GMSKN), N first digital multipliers (M1, M2, ..., MN), and N second digital multipliers (MM1, MM2, ..., MMN); the whole digital modules being connected to N buses (BS1, BS2, ..., BSN) for transferring the N broad band intermediate frequency replicas (IF1, IF2, ..., IFN) towards as many digital to analogue converters (D/A), through a binary tree of N two-inputs digital adders (1, 2, ..., N).

14. Testing system according to claim 12 or 13, characterized in that said control processor (CNTR_PC) transfers to said interface means (INTF_PC, LO_CORP) said control messages (SIM_D, SIM_BEAM_W1, SIM_BEAM_W2, ..., SIM_BEAM_WN SIM_NCO, OL) at sequential time intervals of identical duration.

15. Testing system according to claim 14, characterized in that said identical duration of the sequential time intervals is such that the variation speed of the contents of said messages is similar to that which can be detected in corresponding parameters of a real scenario.

16. Testing system according to any claim from 12 to 15, characterized in that said messages are obtained from the conversion of general tables (TAB.1, TAB.2, ..., TABK) of parameters and options defining a simulated scenario, stored into said control processor (CNTR_PC).

17. Testing system according to claim 16, characterized in that said general tables (TAB.1, TAB.2, ..., TABK) are organized in a sequence of K tables cyclically repeated.

18. Testing system according to claim 14, characterized in that said duration is equal to or lower than 4.61 ms.

19. Testing system according to any claim 16 through 18, characterized in that said general tables (TAB.1, TAB.2, ..., TABK) are filled in before the testing and updated during the testing, and the corresponding updated messages are generated in synchronous mode compared to said sequential time intervals.

20. Testing system according to claim 12, characterized in that said carriers are time division multiplexed and said duration corresponds to a frame time.

21. Testing system according to any claim from 16 to 20, characterized in that said general tables (TAB.1, TAB.2, ..., TABK) include also parameters to simulate the presence of noise, the doppler effect due to the speed of the mobiles, and the quick and sudden fadings of the electromagnetic field received, caused by destructive interference by multiple paths or by masking by obstacles encountered by the mobiles in movement.

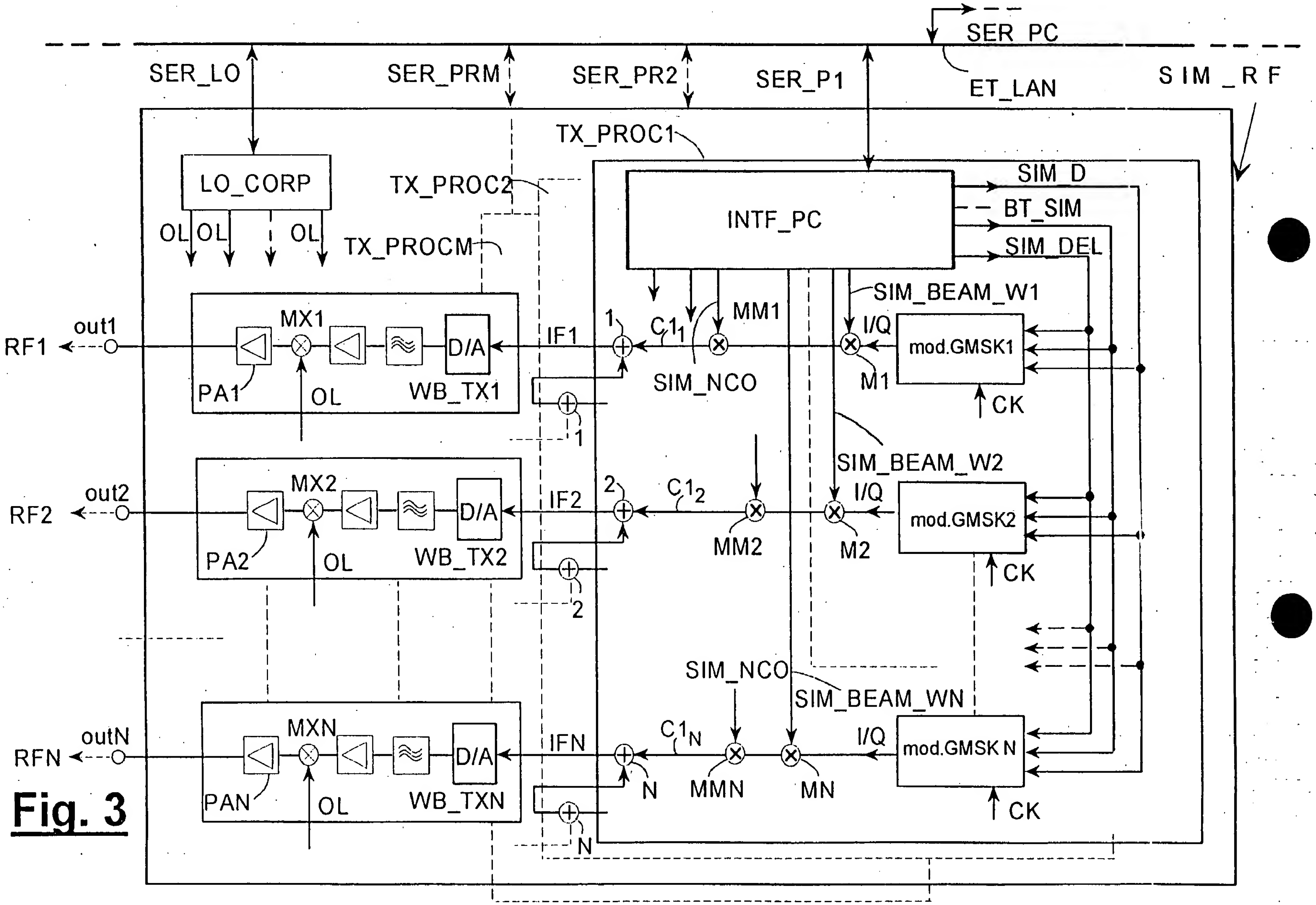
SER_PC
SER_LO
SER_PRM
SER_PR2
SER_P1
ET_LAN
S IM _R F
TX_PROC1
LO_CORP
TX_PROC2
SIM_D
BT_SIM
INTF_PC
SIM_DEL
OL
OL
OL
TX_PROCM
SIM_BEAM_W1
MM1
I/Q
mod.GMSK1
MX1
out1
RF1
PA1
OL
WB_TX1
D/A
IF1
SIM_NCO
M1
CK
SIM_BEAM_W2
mod.GMSK2
MX2
out2
RF2
PA2
OL
WB_TX2
IF2
MM2
M2
CK
SIM_NCO
SIM_BEAM_WN
mod.GMSK N
MXN
outN
RFN
PAN
OL
WB_TXN
IFN
MMN
MN
CK

Fig. 3

TENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference DB 744 PCT	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/EP 98/07762	International filing date *(day/month/year)* 26/11/1998	(Earliest) Priority Date *(day/month/year)* 19/12/1997
Applicant ITALTEL SPA et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 2 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.
   [ ] filed together with the international application in computer readable form.
   [ ] furnished subsequently to this Authority in written form.
   [ ] furnished subsequently to this Authority in computer readble form.
   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).
3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 1

   [X] as suggested by the applicant.
   [ ] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
EP 98/07762

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B17/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 539 772 A (FASULO II ALBERT J ET AL) 23 July 1996 see column 4, line 17 - column 6, line 17; figures 2,3A,3B see column 9, line 66 - column 10, line 32 ---	1,2,13, 14
A	DIOURIS J F ET AL: "MULTISENSOR RECEIVER FOR MOBILE COMMUNICATIONS: AN EXPERIMENTAL STUDY" RECORD OF THE ASILOMAR CONFERENCE ON SIGNALS, SYSTEMS AND COMPUTERS, PACIFIC GROVE, OCT. 30 - NOV. 2, 1994, vol. 1, no. CONF. 28, 30 October 1994, pages 465-469, XP000533603 INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS see the whole document -----	1,2,13, 14

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
20 April 1999	27/04/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Wanzeele, R

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 98/07762

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5539772 A	23-07-1996	NONE	